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State Background Radiation Levels: Results of Measurements Taken During 1975–1979

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STATE BACKGROUND RADIATION LEVELS: RESULTS OF MEASUREMENTS TAKEN DURING 1975-1979

T. E. Myrick, B. A. Berven and F. F. Haywood

ABSTRACT

Background radiation levels across the United States have been measured by the Off-Site Pollutant Measurements Group of the Health and Safety Research Division at Oak Ridge National Laboratory (ORNL). These measurements have been conducted as part of the ORNL program of radiological surveillance at inactive uranium mills and sites formerly utilized during Manhattan Engineer District and early Atomic Energy Commission projects. The measurements included determination of ^{226}Ra, ^{232}Th, and ^{238}U concentrations in surface soil samples and measurement of external gamma-ray exposure rates at 1 m above the ground surface at the location of soil sampling. This information is being utilized for comparative purposes to determine the extent of contamination present at the survey sites and surrounding off-site areas.

The sampling program to date has provided background information at 356 locations in 33 states. External gamma-ray exposure rates were found to range from less than 1 to 34 μR/h, with an U.S. average of 8.5 μR/h. The nationwide average concentrations of ^{226}Ra, ^{232}Th, and ^{238}U in surface soil were determined to be 1.1, 0.98, and 1.0 pCi/g, respectively.

INTRODUCTION

Background radiation levels in the United States have been measured by the Off-Site Pollutant Measurements Group of the Health and Safety Research Division at Oak Ridge National Laboratory (ORNL) from 1975 through 1979. During this time, radionuclide concentrations of ^{226}Ra, ^{232}Th, and ^{238}U in surface soil samples have been determined at 356 locations in 33 states. External gamma-ray exposure rates at 1 m above the ground surface have been measured at all but 29 of these locations. This report presents the results of these background measurements and provides a brief analysis of regional differences and similarities in data values.

These background measurements have been taken so that the collected data would provide a comparison for radiological data obtained during surveys of inactive uranium mills and sites formerly utilized during Manhattan Engineer District (MED) and early Atomic Energy Commission (AEC) projects. A brief history of these programs is provided as follows.

In 1974, the AEC initiated a study of 22 inactive uranium mill sites in cooperation with the Environmental Protection Agency (EPA) and health authorities in the eight affected western states.[1] This study developed into the Inactive Mill Tailings Remedial Action Program whose purpose has been to conduct an engineering assessment of existing conditions at these sites, determine the remedial action required, develop plans and specifications for implementing remedial action, perform the necessary remedial action, verify the results, and release the sites for unrestricted or limited use, as required. The program was divided into three phases. Phase I involved a site visit to assess its radiological condition, need for corrective action, ownership, and present and projected local population.[2] Phase II was the preparation of a detailed engineering assessment of each site including the existing radiation levels, exposure to the public and projected public health implications, practicable remedial actions, and costs of remedial action alternatives.[1,2] The Off-Site Pollutant Measurements Group provided radiological assessments of each of the 22 sites for the Energy Research and

Development Administration [now the Department of Energy (DOE)]. To develop a basis for a radiological assessment of the impact that these sites had on their respective locations, background samples in the western states were collected and analyzed. Phase III in the mill tailings program is the implementation and completion of the remedial action selected in Phase II for the long-term stabilization of the uranium mill tailings at each site.

During the early days of this country's efforts to develop the many uses of nuclear energy, over 150 sites (primarily in the eastern United States) were involved in research, processing, and storage of radioactive ores and residues of the uranium and thorium decay chains. Work at these federally, privately, and institutionally owned facilities were directed by the MED and later AEC. Due to the urgency and magnitude of this early nuclear energy program and to the limited knowledge available to some industrial participants regarding radioactive characteristics of residual material, sites became contaminated.[3] Contracts for needed services were made and terminated as required. However, at termination, the sites were to have been decontaminated according to guidelines then in use. Most of these sites were decontaminated, but since that time many of the radiological records have been lost and radiological criteria for the unrestricted release of these sites have changed. A DOE program was initiated in 1977 to identify all formerly utilized sites, characterize their current radiological status, determine the extent of remedial action (if necesary), and release the sites for unrestricted or limited use, as required. This program is called the Formerly Utilized MED/AEC Sites Remedial Action Program (FUSRAP). The Off-Site Pollutant Measurements Group has assumed a major role in characterizing the current radiological status of these sites. As with the inactive uranium mill sites, background radiation levels were determined in order to understand the significance of radiation levels present at FUSRAP sites.

RADIOLOGICAL MEASUREMENT TECHNIQUES

Measurement of External Gamma-Ray Exposure Rates

External gamma-ray exposure rates were measured with a glass-walled Geiger-Mueller (G-M) tube ("Phil") in association with a battery-powered portable scaler. This instrument is described in Appendix I. The measurements were taken approximately 1 m above the ground surface at the location of the background soil samples. Typically, three 1-min readings were made at each location, and the average value was reported.

Soil Sampling and Radionuclide Analysis

The background surface soil samples were collected from the top 6 cm of the soil, and approximately 600 cm^3 of the soil was placed in a plastic bag. Rocks greater than approximately 2.5 cm diameter were purposely excluded from the sample. The sample was returned to ORNL, where it was dried for 24 h at 110°C and then pulverized to a particle size no greater than 500 μm in diameter (-35 mesh). A 30 cm^3 aliquot of the pulverized sample was sent to the Analytical Chemistry Division at ORNL for ^{238}U concentration analysis by neutron absorption techniques[4] (Appendix II). Other aliquots from the pulverized sample were transferred to plastic bottles, weighed, and stored for approximately 30 d to allow buildup of radon and radon daughters. These aliquots were counted using a germanium lithium-drifted [Ge(Li)] detector, and the spectra obtained were analyzed for the ^{226}Ra and ^{232}Th using computer techniques. A more detailed description of the Ge(Li) detector and soil sample analytical procedure is provided in Appendix II.

LOCATIONS OF STATE BACKGROUND SAMPLES AND MEASUREMENTS

The locations of the background samples and measurements in the United States are shown in Fig. 1. From this map, it is evident that these locations are nonrandom and are positioned along major highways. These locations were selected by several considerations: (1) proximity to or along a route to a site undergoing a radiological survey; (2) accessibility (i.e., closeness to highway); and (3) the degree to which

the location was undisturbed. Those locations were selected which appeared to have been uncultivated or at least fallow for a number of years.

The location of each sample is illustrated by state (alphabetically) in Figs. 2-33. At the present time 33 states have been included in the sampling program, those states being:

Alabama	Indiana	New York
Alaska	Kansas	North Carolina
Arizona	Kentucky	Ohio
Arkansas	Louisiana	Oregon
California	Maryland	Pennsylvania
Colorado	Michigan	Tennessee
Delaware	Mississippi	Texas
Florida	Missouri	Utah
Georgia	Nevada	Virginia
Idaho	New Jersey	West Virginia
Illinois	New Mexico	Wyoming

Additional sampling within these states, as well as sampling in other states, will occur as participation in the FUSRAP program continues.

RESULTS OF MEASUREMENTS

The results of both the external gamma-ray measurements and surface soil sample analyses are presented in Tables 1-33 for each state where samples were taken. The data include the average exposure rate at 1 m above the ground (in μR/h) and the concentration of ^{226}Ra, ^{232}Th, and ^{238}U in surface soil samples (in pCi/g) at each sample location. The tables also provide a brief description of these locations and identification of the sample designation for correlation with locations on the state maps (Figs. 2-33). A total of 356 samples were analyzed from the 33 states. Exposure rate measurements were made in all but 3 of the sampled states (Alaska, Michigan, and New York).

The standard deviation quoted in the results tables for ^{226}Ra, and ^{232}Th concentrations in soil represent only the errors associated with individual sample counting statistics. These values are given as the 2σ (95% confidence) interval. Propogation of errors from sampling methods, sample preparation, and system calibration has not been included. For

the ^{238}U determinations, the 2σ value presented includes all errors except those resulting from the sample collection and preparation.

Summaries of the state background radiation levels and U. S. averages are provided in Tables 34-37 for external gamma-ray exposure rates, ^{226}Ra, ^{232}Th, and ^{238}U concentrations, respectively. Included in these tables are the number of data entries for each state as well as the range of values, the arithmetric mean and standard deviation, and the geometric mean and standard deviation. The geometric statistical analysis is included since environmental samples, are often represented by a lognormal distribution. It should be noted, however, that the geometric standard deviation of the mean is not an additive value, but rather is multiplicative. Hence, for these data, values between one and two indicate a "relatively" good fit to the lognormal distribution. The geometric standard deviations reported contain 68% of the frequency values, and represent a 1σ bound. The arithmetric standard deviations are reported as the 95% confidence (or 2σ) values.

The number of sampling locations within any particular state ranges from 1 (in Arkansas) to 33 (in Pennsylvania). Obviously, the characterization of the average background levels in each state is highly dependent upon the sample size, as well as the randomness of the sample, neither of which could be controlled adequately in this measurement program. In addition, local variability in soil types and geologic conditions can result in a wide range of "background" values for any particular area. Therefore, use of the mean state values for comparative purposes must be exercised with caution, as the values reported may not adequately characterize the state as a whole. However, continued sampling, as part of this program, will help to define further these state background levels.

External gamma-ray exposure rates, measured at 1 m above the ground, were found to range from less than 1 to 34 μR/h. State averages were in the range of 3.3 μR/h (Texas) to 14 μR/h (Colorado, Nevada, and Wyoming) with a U. S. average of 8.5 μR/h. The standard deviations of the means indicate the significant variability of the individual values within a state (23 to 91% relative arithmetic standard deviation, range of geometric standard deviation of 1.1 to 1.7). A graphical representation of

the distribution of the state average external gamma-ray exposure rate is given in Fig. 34. The grouping presented in this figure suggests regional differences in the background gamma radiation levels, with western states showing generally higher values than the Gulf Coast, mid-Atlantic, or mid-western states.

The soil sample analysis resulted in estimates of the mean values for ^{226}Ra, ^{232}Th, and ^{238}U concentrations in surface soil in each of the surveyed states. Figures 35-37 depict the distribution of the state averages, with a strikingly similar pattern occurring for all three radionuclides. This pattern groups the states with lower concentrations generally in the coastal regions, with the higher concentrations occurring in the continental interior states. The state average ^{226}Ra concentration in surface soil was found to vary from 0.65 pCi/g (Alaska) to 1.5 pCi/g (Kentucky, Nevada, New Mexico, and Ohio). Relative arithmetic standard deviations ranged from 12 to 158% for the state averages. Individual ^{226}Ra measurements ranged from 0.23 to 4.2 pCi/g. For ^{232}Th, concentrations in individual samples were found from 0.10 to 3.4 pCi/g, with the state averages ranging from 0.24 pCi/g (Florida) to 1.6 pCi/g (Arkansas). Again, the relative arithmetic standard deviations indicate the variability of the sample concentrations and the small sample size, with values of 12 to 173%. State averages for ^{238}U concentration in surface soil vary from 0.58 pCi/g (Louisiana) to 1.6 pCi/g (Kentucky), with relative arithmetic standard deviations from 8 to 183%. Individual samples had ^{238}U concentrations from 0.12 to 3.8 pCi/g. The average concentrations in the United States for all three nuclides were 1.1, 0.98, and 1.0 pCi/g for ^{226}Ra, ^{232}Th, and ^{238}U, respectively.

DISCUSSION OF RESULTS

External Gamma-Ray Exposure Rates

Several investigators have conducted ground surveys of natural terrestrial radiation in the United States, using a variety of detection methods.[5-15] Table 38 presents a summary of the more extensive of these measurement programs. Of these surveys, those conducted by Beck,[7,15] Levin,[11] and Lindeken[14] are the most comprehensive and best suited for

comparison with the data obtained during the ORNL program presented in this report. The detection methods utilized in these four investigations were all different, and although the choice of instrumentation utilized influences the utility of the data, comparison of the measurement results is still useful.

Table 39 provides a comparison of the average gamma-ray exposure rates in the United States as measured by the investigators cited above and the results presented in this report. With few exceptions, the data are consistent on both state-by-state and national averages. This is somewhat surprising considering the wide variations in sample size and locations, and instrumentation and methods employed. It should again be emphasized that use of these data for characterization of individual states should be exercised with caution due to the extremely small sampling population in particular states.

The regional differences in external gamma-ray exposure rates highlighted in the previous section of this report are consistent with the results obtained by Oakley.[16] In the analysis of Aerial Radiological Measurement Surveys (ARMS), it was concluded that the United States is divided into three fairly distinct terrestrial radiation zones: the coastal plain including all or portions of states bordering the Atlantic Ocean and the Gulf of Mexico; the Colorado Range consisting of those states situated along the Rocky Mountains; and the noncoastal plain composed of the remaining states. Figure 34, representing the ORNL data, shows a strikingly similar zonal pattern, with Gulf-coast states exhibiting the lowest average external gamma-ray exposure rates, mid-Atlantic states grouping at the next level, and Colorado Range and western states showing the highest exposure rates.

Isotopic Distribution of Radionuclides in Soil

A common feature in many environmental radiation measurement programs is the determination of radionuclide distributions and concentrations in surface soil. Data of this type have been accumulated during recent years by many investigators, directed toward a variety of goals. This considerable but scattered literature has been summarized by the

United Nations Scientific Committee on the Effects of Atomic Radiation in a number of reports, most recently in their UNSCEAR 1977 edition.[17]

The radioactivity of soil depends upon that of the parent rock as well as the soil formation and transport processes that were involved. In the course of such rock weathering and soil formation, chemical and biochemical interactions dynamically influence the distribution patterns of uranium and thorium, as well as all the radionuclides created by the radioactive decay of these elements. Typical uranium, thorium, and radium contents of a wide variety of soils in North America and Europe are listed in Table 40. These observed concentrations are a strong function of soil type and soil horizon, with significant variation of soil radioactivity with location and depth being common.[18] The values obtained during the measurement program presented in this report compare favorably with the literature values. The mean U. S. concentrations for ^{226}Ra, ^{238}U, and ^{232}Th of 1.1, 0.98, and 1.0 pCi/g fall within the range of observed values and are only slightly above the tabulated world averages.

The relatively few simultaneous measurements of the uranium and radium concentrations in soil indicate that radioactive equilibrium is roughly obtained in many soils, but large deviations from equilibrium are also observed due to the different geochemical properties of uranium and radium compounds.[19] Departure from equilibrium occurs even more readily for those ^{238}U daughters beyond ^{222}Rn because of the escape of gaseous radon from the soil matrix with subsequent migration elsewhere prior to decay. The correlation between the radium and uranium concentration data presented in the previous section was computed for the 346 sampling locations where simultaneous measurements had been made. The correlation coefficient for these data was determined to be 0.77, indicating good correlation, especially for this type of field measurement. The U. S. average concentrations of radium and uranium showed a nearly 1 to 1 correlation, signififying that at least on such a gross level, radioactive equilibrium exists.

External Gamma-Ray Exposure Rates vs Radionuclide Concentrations in Soil

Analysis of the data for correlation between the external gamma-ray levels and radionuclide concentrations in the soil was conducted for each radionuclide measured, as well as the combination of all three. The correlation coefficients obtained were 0.48, 0.35, and 0.33 for gamma vs ^{232}Th, gamma vs ^{226}Ra, and gamma vs ^{238}U, respectively. The relative magnitude of the coefficients reflect the respective average gamma-ray energy per disintegration of each decay chain (1.9 MeV for ^{232}Th, and 1 MeV for the ^{238}U and ^{226}Ra chains). Further regression analyses confirmed the correlation for both linear and logarithmic regressions. The coefficient of determination (r^2) values for each individual correlation, as well as the correlation between the dependent and two or more independent variables are given in Table 41. These results suggest that other factors, such as the magnitude of the cosmic-ray contribution, emanation of radon from the soil, and the presence of other radionuclides in soil and rocks, are important in the correlation with external gamma-ray exposure rates, as would be expected. In addition, measurement errors in both exposure rate determinations and radionuclide concentrations would affect the observed degree of correlation.

SUMMARY

Background radiation levels across the United States have been measured by the Off-Site Pollutant Measurements Group of the Health and Safety Research Division at ORNL, as part of their program of radiological surveillance at inactive uranium mills and FUSRAP sites. This information is being utilized for comparative purposes to determine the extent of contamination present at the survey sites. The background measurements included determination of ^{226}Ra, ^{232}Th, and ^{238}U concentrations in surface soil samples, and detection of external gamma-ray exposure rates at 1 m above the surface at the locations of soil sampling. Data were collected at 356 nonrandom, relatively undisturbed areas in a total of 33 states from 1975 through 1979. Additional sampling will be conducted as participation in the FUSRAP program continues.

External gamma-ray levels, as measured with a glass-walled, energy-compensated G-M tube, were found to range from less than 1 to 34 μR/h. State averages varied from 3.3 μR/h (Texas) to 14 μR/h (Colorado, Nevada, and Wyoming), with a U. S. average of 8.5 μR/h. The state average ^{226}Ra concentrations in surface soil, as determined by gamma spectroscopy, ranged from 0.65 pCi/g (Alaska) to 1.5 pCi/g (Kentucky, Nevada, New Mexico, and Ohio). Individual measurements ranged from 0.23 to 4.2 pCi/g. For ^{232}Th concentrations, also determined by gamma spectroscopy, individual samples contained from 0.10 to 3.4 pCi/g, with state averages ranging from 0.24 pCi/g (Florida) to 1.6 pCi/g (Arkansas). Analysis for ^{238}U concentrations in soil, as determined by neutron absorption techniques, resulted in individual values ranging from 0.12 to 3.8 pCi/g. State average ^{238}U concentrations varied from 0.58 pCi/g (Louisiana) to 1.6 pCi/g (Kentucky). The average concentrations in the United States were 1.1, 0.98, and 1.0 pCi/g for ^{226}Ra, ^{232}Th, and ^{238}U, respectively. The correlation between the radium and uranium concentrations was good (correlation coefficient of 0.77), indicating that radioactive equilibrium is roughly obtained in most samples. The geographical distribution of background levels for the external gamma-ray measurements as well as the radionuclide concentrations in soil samples was similar. Regional differences were evident, with western states showing generally higher values than coastal or mid-eastern areas.

Analysis of the correlation between the external gamma radiation levels and the radionuclide concentrations in soil did not indicate a strong relationship between these parameters. Correlation coefficients ranged from 0.33 to 0.48. Further regression analysis confirmed this assessment for both linear and logarithmic regressions. These results suggest that other factors, such as the cosmic-ray contribution, radon emanation, and the presence of other radionuclides in soil and rocks, are significant in the correlation with external gamma-ray exposure rates.

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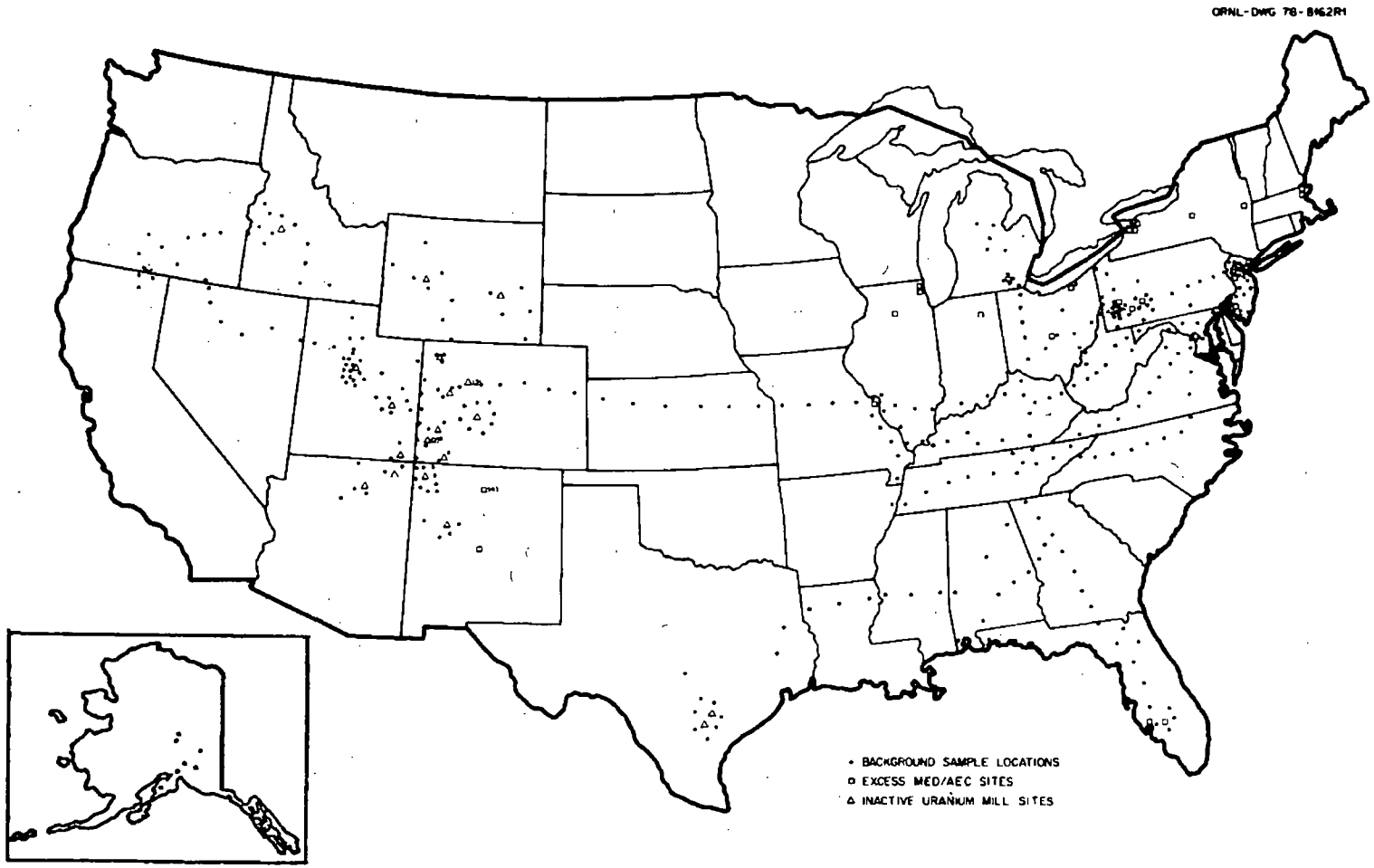

Fig. 1. Location of background soil samples and external gamma-ray exposure rate measurements in the United States.

Table 1. Background radiation levels and nuclide concentrations in surface soil samples in the State of Alabama

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
AL-1	Approx. 1.6 km S of I-65 on W side of Hwy 17	3.7	0.59 ± 0.02	0.65 ± 0.04	0.67
AL-2	Approx. 3.2 km S of I-85 on Hwy 15, about 17 km W of Alabama-Georgia line	7.8	1.0 ± 0.14	0.87 ± 0.06	0.95
AL-3	Approx. 1.5 km S of I-85 on Hwy 80 near Hwy 229 turnoff, N side of road	4.4	1.4 ± 0.10	1.5 ± 0.10	0.95
AL-4	Approx. 1.2 km W of I-65 on Hwy 106 in front of small church and graveyard, N side of road	3.7	0.49 ± 0.04	0.36 ± 0.08	0.51
AL-5	Rest area at end of I-10 (headed west)	3.2	0.47 ± 0.08	0.44 ± 0.02	0.83
AL-6	Roadside park, ~8.1 km N of York, Alabama on E side of Hwy 11 at mile marker 11	6.5	0.93 ± 0.04	1.0 ± 0.08	0.91
AL-7	W side of frontage road off I-59 at mile marker 148.8	6.1	0.70 ± 0.02	0.67 ± 0.04	0.85
AL-8	Approx. 0.5 km W of I-59 (exit 231) N side of Hwy 40	3.0	0.99 ± 0.06	0.63 ± 0.04	1.1

[a]Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b]Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

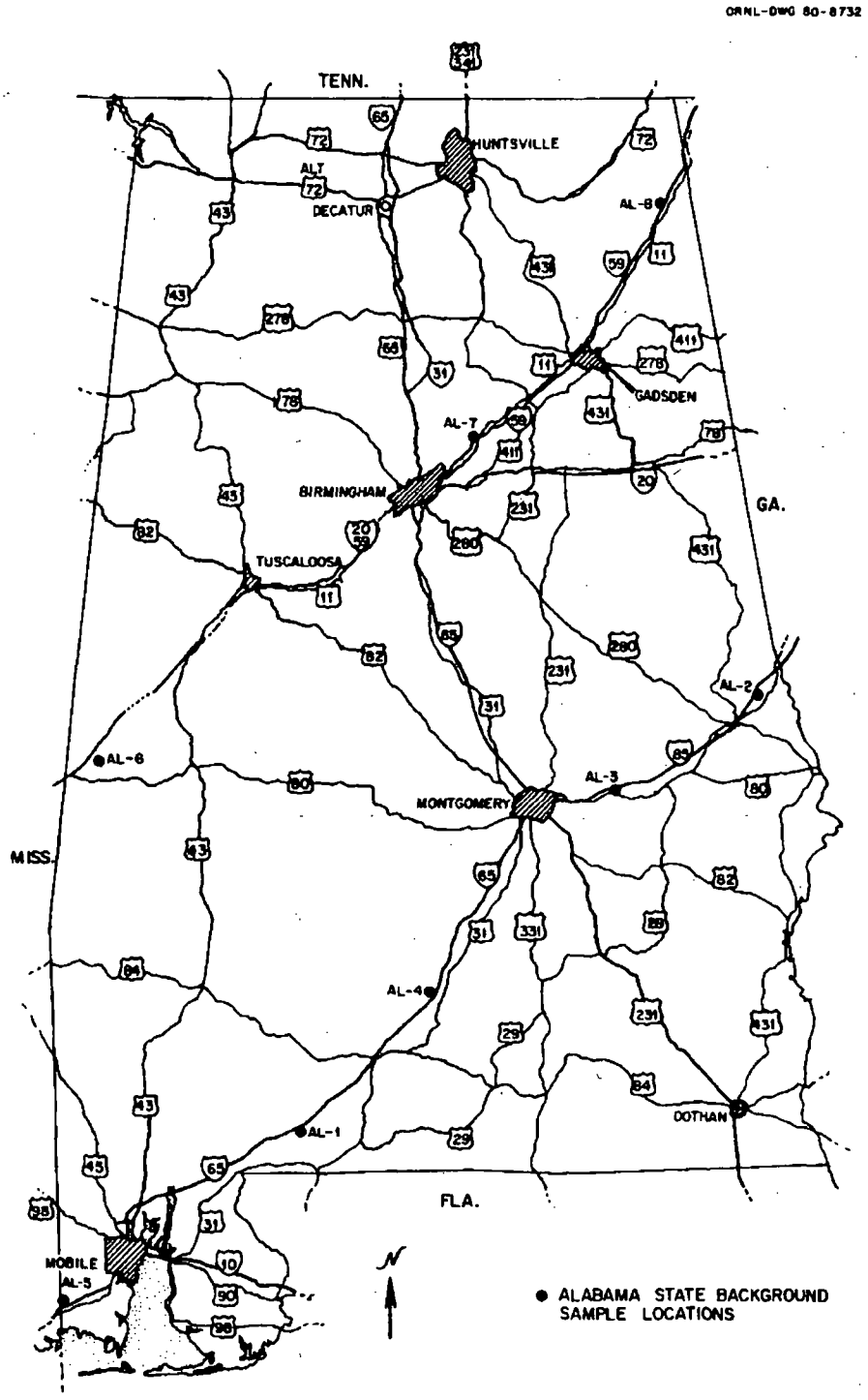

Fig. 2. Location of background samples and external gamma-ray exposure rate measurements in Alabama.

Table 2. Background radiation levels and nuclide concentrations in surface soil samples in the State of Alaska

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
AK-1	S side of Tanana River, ~13 km SE of the city limits of Fairbanks, Alaska	[c]	0.66 ± 0.12	0.98 ± 0.20	0.62
AK-2	Approx. 62 km NE of Fairbanks, Alaska, N side of Hwy 6	[c]	0.59 ± 0.08	0.66 ± 0.08	0.64
AK-3	N side of Hwy 3, at Wasilla, Alaska	[c]	[d]	0.19 ± 0.12	0.39
AK-4	Approx. 40 km E of Kenai, Alaska, on the S side of Hwy 1, just below confluence of Russian and Kenai Rivers	[c]	0.92 ± 0.12	0.98 ± 0.22	0.80
AK-5	N side of Hwy 1, ~95 km W of Glenallen, Alaska	[c]	0.73 ± 0.10	0.56 ± 0.12	0.77
AK-6	Approx. 5 km S of Glenallen, Alaska, on the W side of Hwy 4	[c]	0.59 ± 0.06	2.3 ± 0.80	0.70
AK-7	Approx. 24 km S of Tok Junction, Alaska, on W side of Hwy 1	[c]	0.43 ± 0.04	0.40 ± 0.04	0.46

[a] Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b] Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

[c] No data obtained.

[d] Nuclide not found.

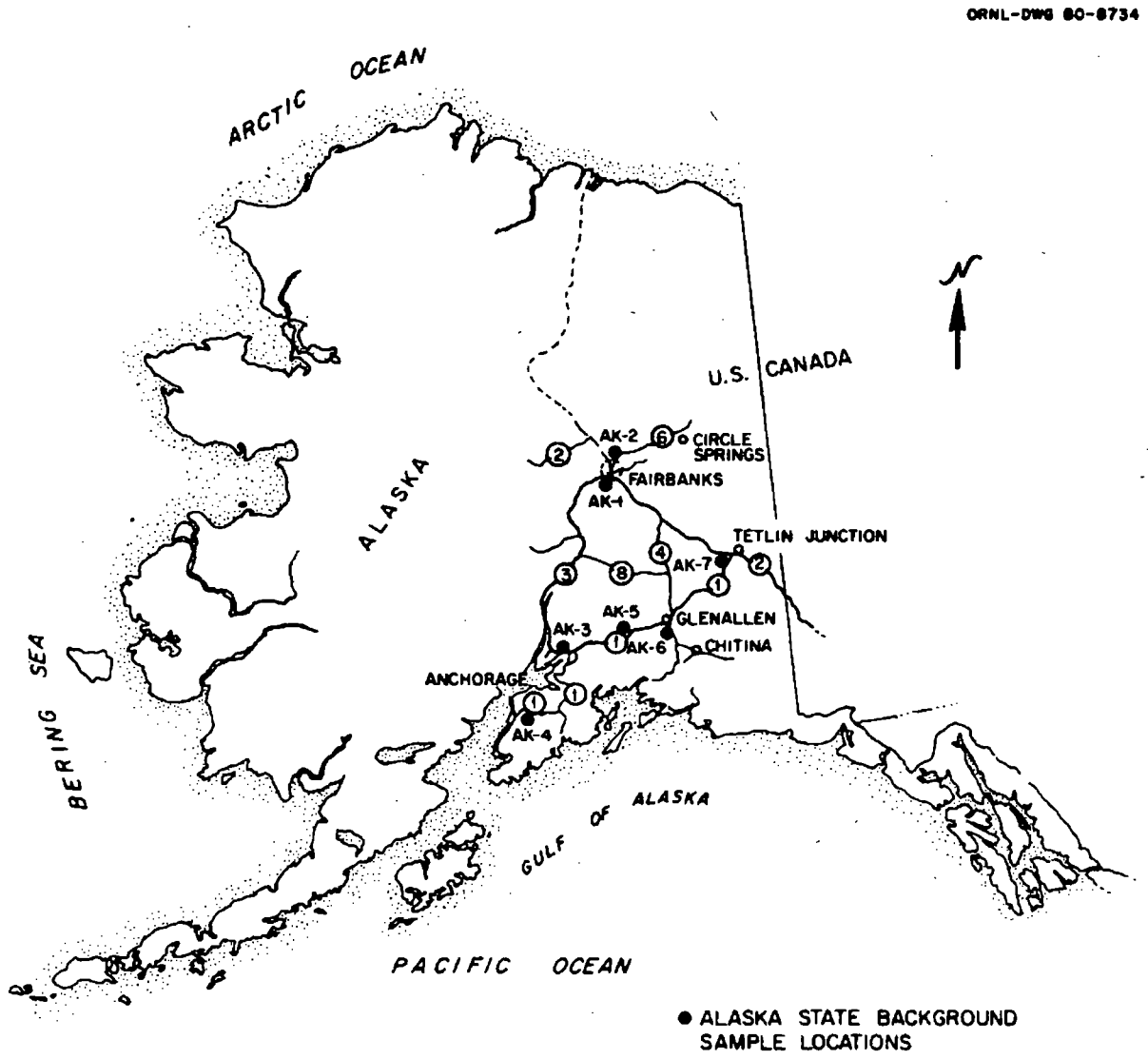

Fig. 3. Location of background samples and external gamma-ray exposure rate measurements in Alaska.

Table 3. Background radiation levels and nuclide concentrations in surface soil samples in the State of Arizona

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
AZ-1	In valley 9.7 km S of uranium mill tailings at Monument Valley, Arizona	9.5	1.7 ± 0.08	0.46 ± 0.08	0.97
AZ-2	S side of Hwy 64, ~0.6 km W of intersection of Hwys. 89 and 64	10	0.93 ± 0.10	1.3 ± 0.12	0.92
AZ-3	N side of Hwy 89, 2.4 km E of Glen Canyon Dam (mile marker 548)	5.3	0.23 ± 0.06	0.20 ± 0.08	0.27
AZ-4	S side of Hwy 160, ~0.4 km E of intersection of Hwys 160 and 89	12	2.0 ± 0.10	1.0 ± 0.16	1.8
AZ-5	Near rest stop on Hwy 264, 11.4 km E of Tuba City, Arizona	6.8	0.40 ± 0.06	0.39 ± 0.06	0.47
AZ-6	S side of Hwy 160, 3.2 km W of Kayenta, Arizona	12	0.42 ± 0.10	0.42 ± 0.04	0.43

[a]Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b]Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

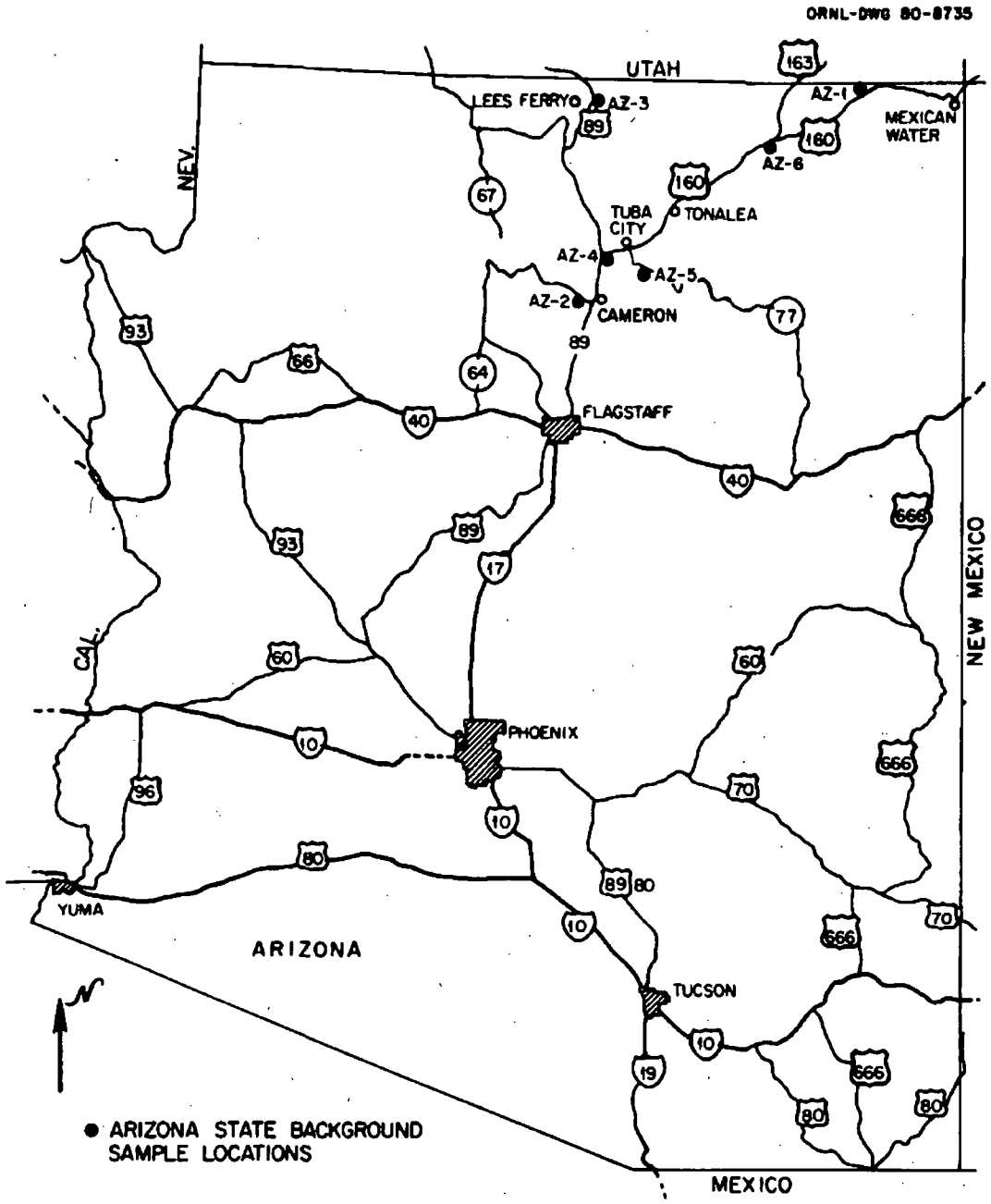

Fig. 4. Location of background samples and external gamma-ray exposure rate measurements in Arizona.

Table 4. Background radiation levels and nuclide concentrations in surface soil samples in the State of Arkansas

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
AR-1	Rest area W side of I-55, ~16 km NE of Gilmore, Arkansas	11	[c]	1.6 ± 0.24	1.6

[a] Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b] Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

[c] Nuclide not found.

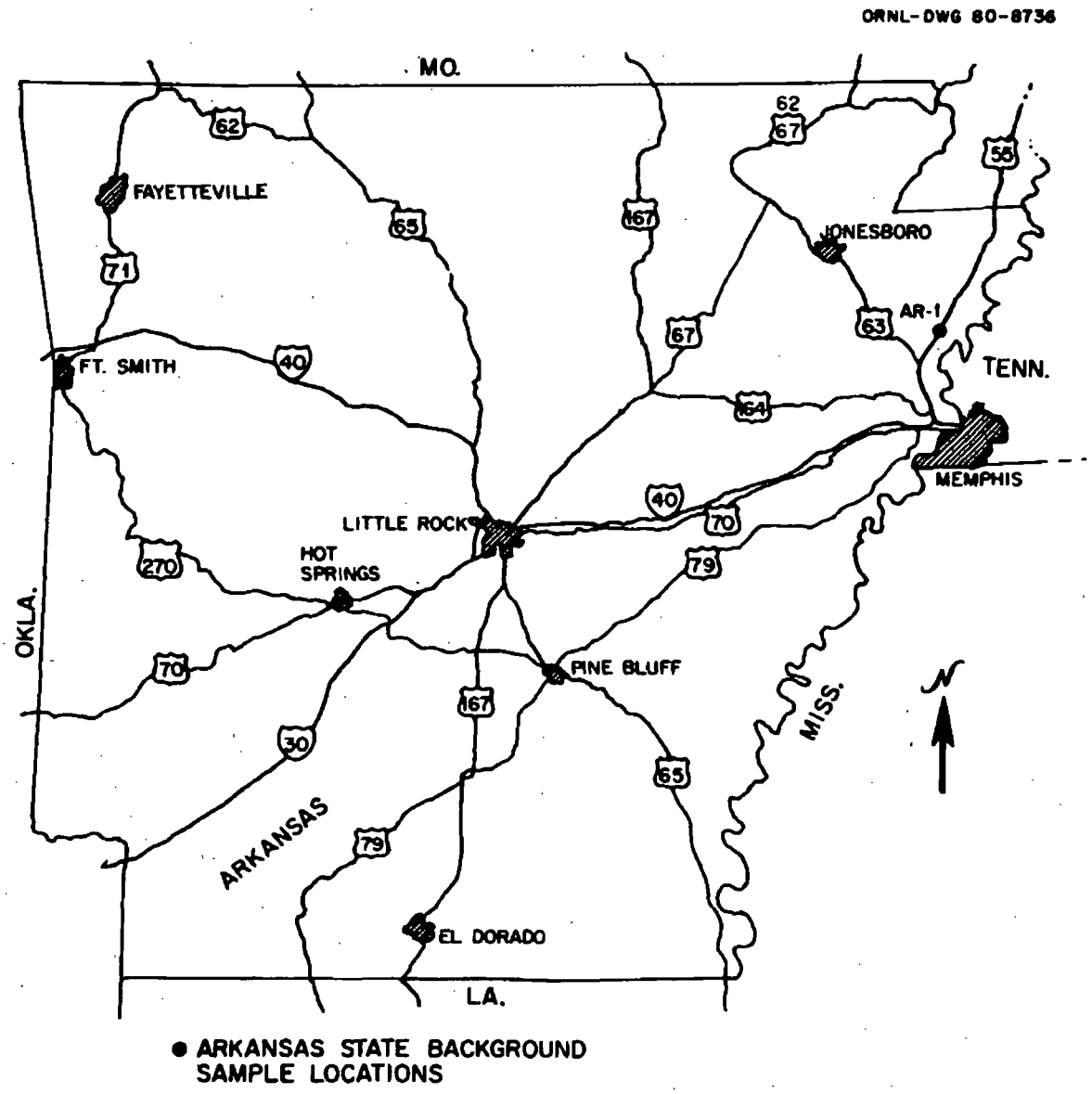

Fig. 5. Location of background samples and external gamma-ray exposure rate measurements in Arkansas.

Table 5. Background radiation levels and nuclide concentrations in surface soil samples in the State of California

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
CA-1	W side of Hwy 395 at junction of Hwys 395 and 46, near Goose Lake, in Northern California	9.0	1.3 ± 0.04	0.76 ± 0.08	1.3
CA-2	E side of Hwy 48, S of Goose Lake, S end of causeway	11	0.78 ± 0.04	0.55 ± 0.04	0.83
CA-3	E side of Hwy 48, W side of Goose Lake at Crowder Flats turnoff	11	0.24 ± 0.04	0.30 ± 0.04	0.19

[a] Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b] Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

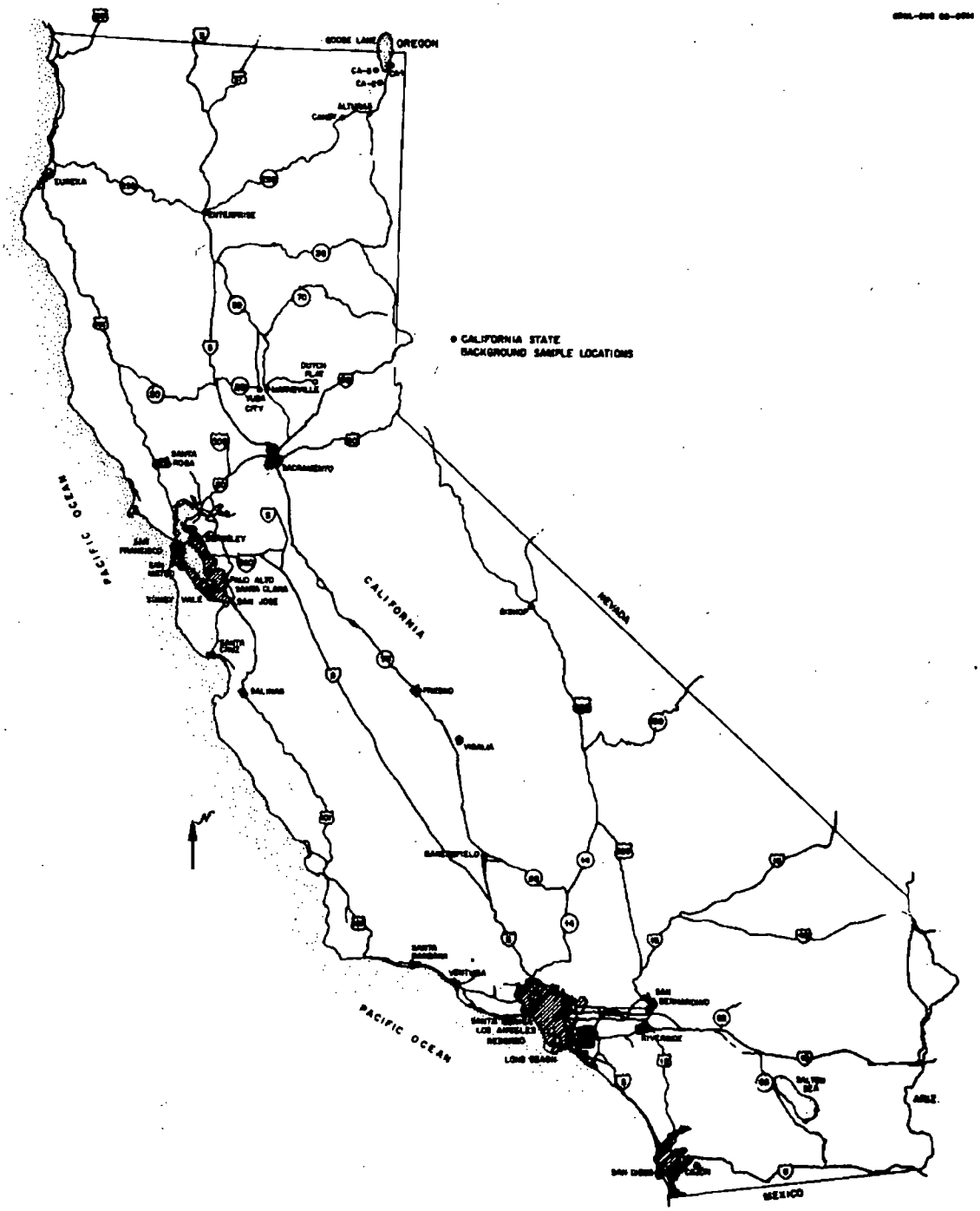

Fig. 6. Location of background samples and external gamma-ray exposure rate measurements in California.

Table 6. Background radiation levels and nuclide concentrations in surface soil samples in the State of Colorado

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
CO-1	1.6 km N of Colorado-New Mexico border, E side of Hwy 550	15	1.1 ± 0.12	1.1 ± 0.10	0.95
CO-2	Approx. 8 km S of Montrose, Colorado, E side of Hwy 550	15	1.5 ± 0.08	1.2 ± 0.22	1.2
CO-3	W side of Hwy 141, ~1.6 km S of Gateway, Colorado	10	3.4	0.42 ± 0.02	1.9
CO-4	Junction of Hwys 666 and 141, NW side of Hwy 141	8.1	1.9 ± 0.10	0.10 ± 0.02	1.1
CO-5	S of I-70 at Colorado-Utah border	6.3	0.96 ± 0.12	c	0.54
CO-6	Approx. 2 km E of Utah-Colorado border, S side of Hwy 41	7.1	0.54 ± 0.04	0.58 ± 0.06	0.62
CO-7	Intersection of Hwy 172 and 309, W side of Hwy 309, ~1.6 km from La Plata City airport	9.9	1.2	c	1.2
CO-8	Adjacent to Hwy 666 at Pleasant View, Colorado	12	1.2	c	0.99
CO-9	Approx. 45 km S of intersection of Hwys 141 and 145	13	1.6	1.2 ± 0.08	1.5
CO-10	Beside road at Erikson Springs, Colorado, between Crested Butte and Paonia	13	1.5	c	1.2
CO-11	Approx. 0.4 km S of Crested Butte, Colorado, W side of Hwy 135	22	<2.0	c	1.3
CO-12	SE side of intersection of road at Spur Guest Ranch	21	1.2	c	1.0
CO-13	S side of Hwy 50, at Sargents, Colorado	19	2.1	1.5 ± 0.06	3.0
CO-14	S side of Hwy 114 at North Cochetopa Pass	16	1.3	c	1.1
CO-15	Intersection of roads to Powerhorn and Lake City, Colorado, S side of road	13	1.3	c	1.3
CO-16	Big Blue turnoff on Hwy 149 between Powerhorn and Lake City, Colorado, NW of intersection	15	1.4	c	1.3
CO-17	Approx. 450 m above Big Blue Mesa Dam Reservoir, N of Hwy 50, S side of lake	18	0.91	1.5 ± 0.04	1.3
CO-18	SW side of Hwy 145 at Placerville, Colorado, 275 m W of intersection	15	0.85	c	1.0

Table 6. (continued)

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
CO-19	N side of Hwy 90 at Utah-Colorado border	15	1.6	[c]	1.5
CO-20	W side of Hwy 139 immediately across Douglass Pass going N	16	2.2 ± 0.06	1.3 ± 0.06	1.8
CO-21	S side of Hwy 330 at Colbran, Colorado, intersection with county road	9.3	1.9 ± 0.04	1.1 ± 0.18	1.6
CO-22	DeBeque, Colorado, N of intersection of county road and Hwy 6-24	10	1.3 ± 0.04	2.1 ± 2.6	1.3
CO-23	Approx. 1.9 km SE of Glenwood Springs, Colorado, NE side of Hwy 82	15	1.2 ± 0.10	[c]	1.2
CO-24	Approx. 3.2 km W of Lay Colorado Post Office, N side of Hwy 40	11	1.4 ± 0.08	1.1 ± 0.10	1.3
CO-25	Intersection of Moffat County roads 17 and 119	11	0.65 ± 0.06	0.78 ± 0.04	0.66
CO-26	Intersection of Moffat County road 57 and Hwy 50, E side of 57	11	0.48 ± 0.06	0.58 ± 0.06	0.47
CO-27	S side of Hwy 6, 4.8 km E of intersection of Hwy 82 and I-70 in Glenwood Springs, Colorado	14	1.2 ± 0.08	1.2 ± 0.08	1.1
CO-28	SW corner of intersection of I-70 and Hwy 24	19	1.8 ± 0.16	3.1 ± 1.6	0.99
CO-29	Approx. 6.8 km E of Eisenhower Tunnel on S side of I-70	34	1.8 ± 0.12	2.9 ± 2.2	1.7
CO-30	SW corner of intersection of Manila Rd and I-70, 27 km E of Denver, Colorado	17	1.3 ± 0.08	1.5 ± 1.2	1.2
CO-31	SE corner of intersection of Hwy 40-287 and I-70, ~130 km E of Denver, Colorado	14	1.3 ± 1.2	1.1 ± 0.8	1.1
CO-32	Burlington, Colorado, at SW corner of intersection of Hwy 388 and I-70	14	1.3 ± 0.06	1.4 ± 0.08	1.1

[a]Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b]Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

[c]Nuclide not found.

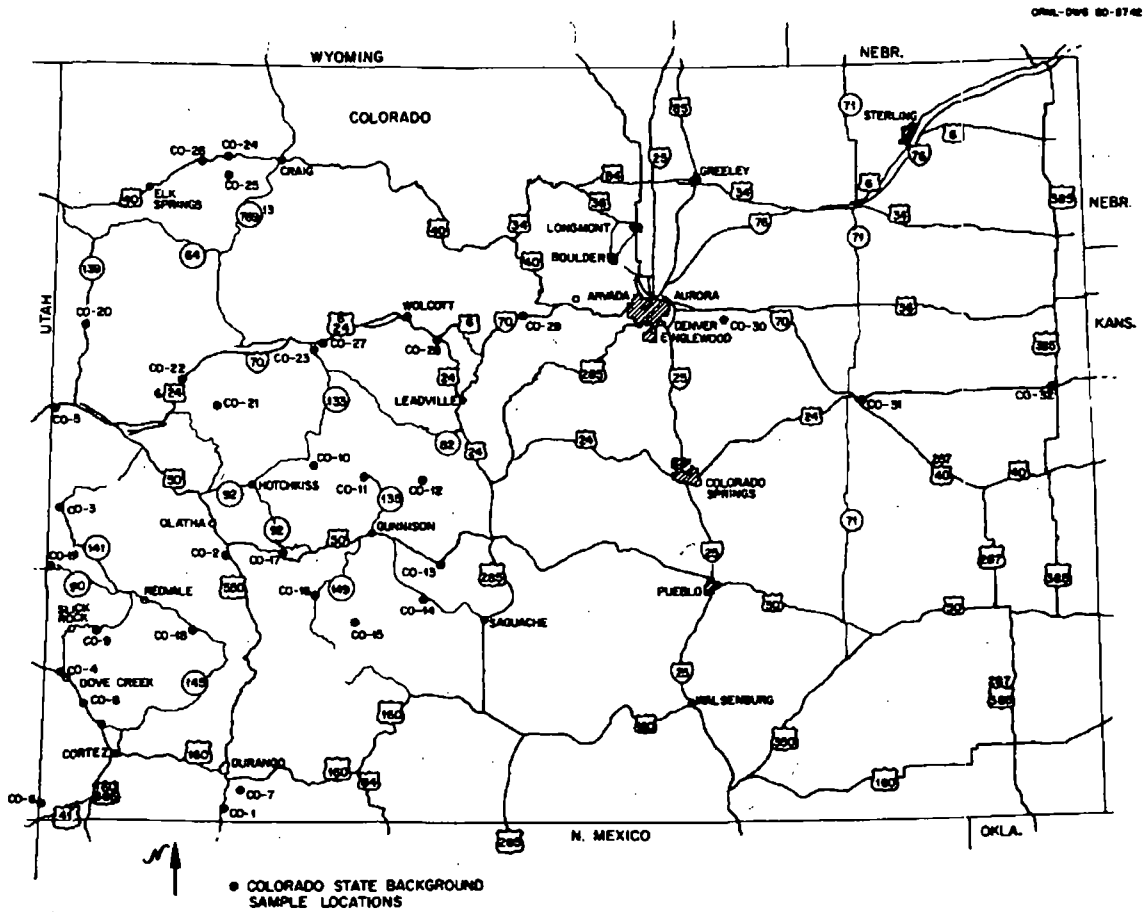

Fig. 7. Location of background samples and external gamma-ray exposure rate measurements in Colorado.

Table 7. Background radiation levels and nuclide concentrations in surface soil samples in the State of Delaware

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
DEL-1	E side of Hwy 301, S end of Summit Bridge	6.9	1.1 ± 0.06	1.2 ± 0.06	1.1
DEL-2	SE corner of intersection of I-95 and March Rd, N side of Wilmington, Delaware	5.0	1.2 ± 0.06	1.2 ± 0.08	1.2

[a]Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b]Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

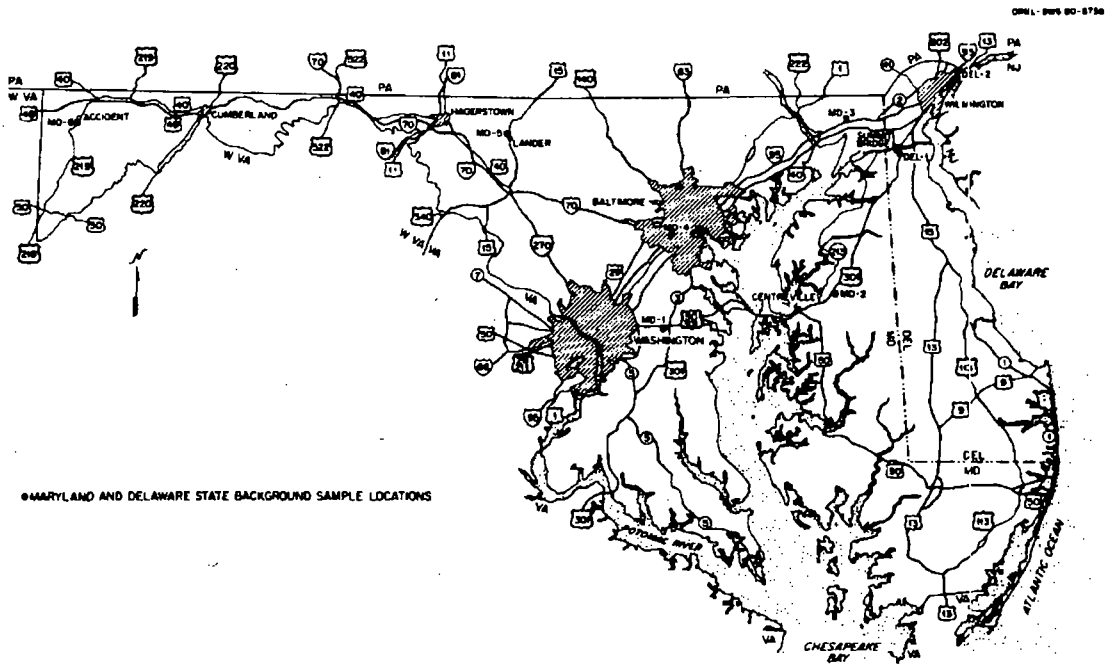

Fig. 8. Location of background samples and external gamma-ray exposure rate measurements in Delaware and Maryland.

Table 8. Background radiation levels and nuclide concentrations in surface soil samples in the State of Florida

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
FL-1	N side of I-10, midway between Jacksonville, Florida, and intersection of I-10 and I-75	4.4	0.47 ± 0.10	0.21 ± 0.02	0.23
FL-2	S of Starke, Florida, on US 301, just N of Hwy 227 on W side of hwy	[c]	0.41 ± 0.06	0.29 ± 0.06	[d]
FL-3	NE of intersection of Hwys 60 and 39, ~10 km S of Plant City, Florida	4.1	1.4 ± 0.10	0.25 ± 0.08	1.8
FL-4	Approx. 4.5 km S of Fort Mead, Florida, SW side of intersection of Hwy 17 and unmarked dirt road	4.7	1.2 ± 0.12	0.25 ± 0.02	0.98
FL-5	Approx. 11 km W of Arcadia, Florida, on Hwy 72, W side of Horse Creek	7.4	2.3 ± 0.14	0.20 ± 0.04	2.0
FL-6	N side of bridge between Bradenton and Palmetto, Florida, on E side of Hwy 41	3.8	0.97 ± 0.04	[d]	1.1
FL-7	NE corner of intersection of I-75 and Hwy 54 near Zephyrhills, Florida	2.7	0.25 ± 0.04	0.12 ± 0.04	0.20
FL-8	E side of I-75, 2.4 km N of Hwy 44	4.1	0.67 ± 0.04	0.37 ± 0.04	0.30
FL-9	E side of I-75, 1.6 km S of Micanopy exit at mile marker 144	4.3	0.83 ± 0.12	0.21 ± 0.04	0.56
FL-10	Intersection of I-75 and Hwy 90, W of Lake City, Florida	4.8	0.45 ± 0.08	0.26 ± 0.04	0.15
FL-11	E side of I-75 across from welcome station at Florida-Georgia border	2.5	[d]	[d]	0.12
FL-12	Intersection of Scenic Hwy and Summit Blvd., Pensacola, Florida	<1.0	0.28 ± 0.02	0.26 ± 0.02	0.42

[a] Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b] Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

[c] No data obtained.

[d] Nuclide not found.

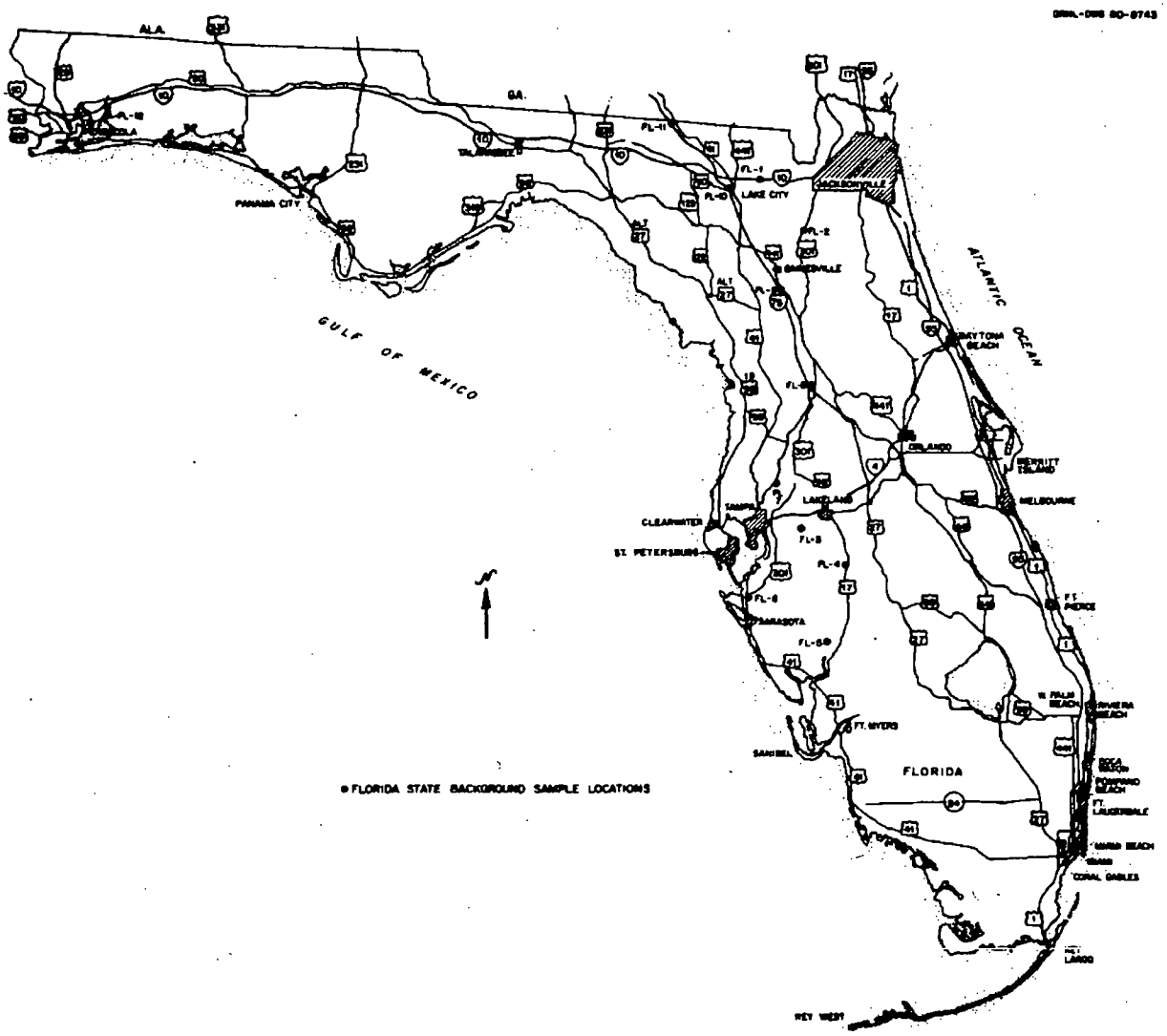

Fig. 9. Location of background samples and external gamma-ray exposure rate measurements in Florida.

Table 9. Background radiation levels and nuclide concentrations in surface soil samples in the State of Georgia

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
GA-1	NE corner of intersection of I-75 and Hwy 37, near Adel, Georgia	4.9	0.50 ± 0.02	0.28 ± 0.04	0.48
GA-2	Approx. 0.4 km N of Arabi exit on I-75, E side of road	3.1	0.46 ± 0.04	0.47 ± 0.32	0.48
GA-3	E side of I-75, ~1.6 km S of Perry, Georgia, exit	3.7	0.80 ± 0.04	0.78 ± 0.04	0.62
GA-4	E side of I-75, ~1.6 km S of Rumble Rd, near Forsyth, Georgia	1.9	0.81 ± 0.04	0.87 ± 0.04	0.87
GA-5	NE corner of intersection of I-75 and Hwy 138, S of Morrow, Georgia	4.4	0.68 ± 0.02	0.61 ± 0.04	0.67
GA-6	NE corner of I-75 and Emerson-Alatoona intersection	6.1	1.3 ± 0.02	1.9 ± 0.10	1.1
GA-7	Rest stop, E side of I-75, ~3.2 km N of Dalton, Georgia	6.5	0.6 ± 0.06	0.84 ± 0.08	0.71
GA-8	Approx. 0.8 km N of I-85 at Palmetto exit at mile marker 56	6.7	1.6 ± 0.08	3.4 ± 0.16	1.6
GA-9	Approx. 1.2 km N of I-85 on Hwy 109, 0.4 km E on Hwy 14, S side of road	9.0	1.2 ± 0.06	0.76 ± 0.06	1.1

[a]Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b]Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

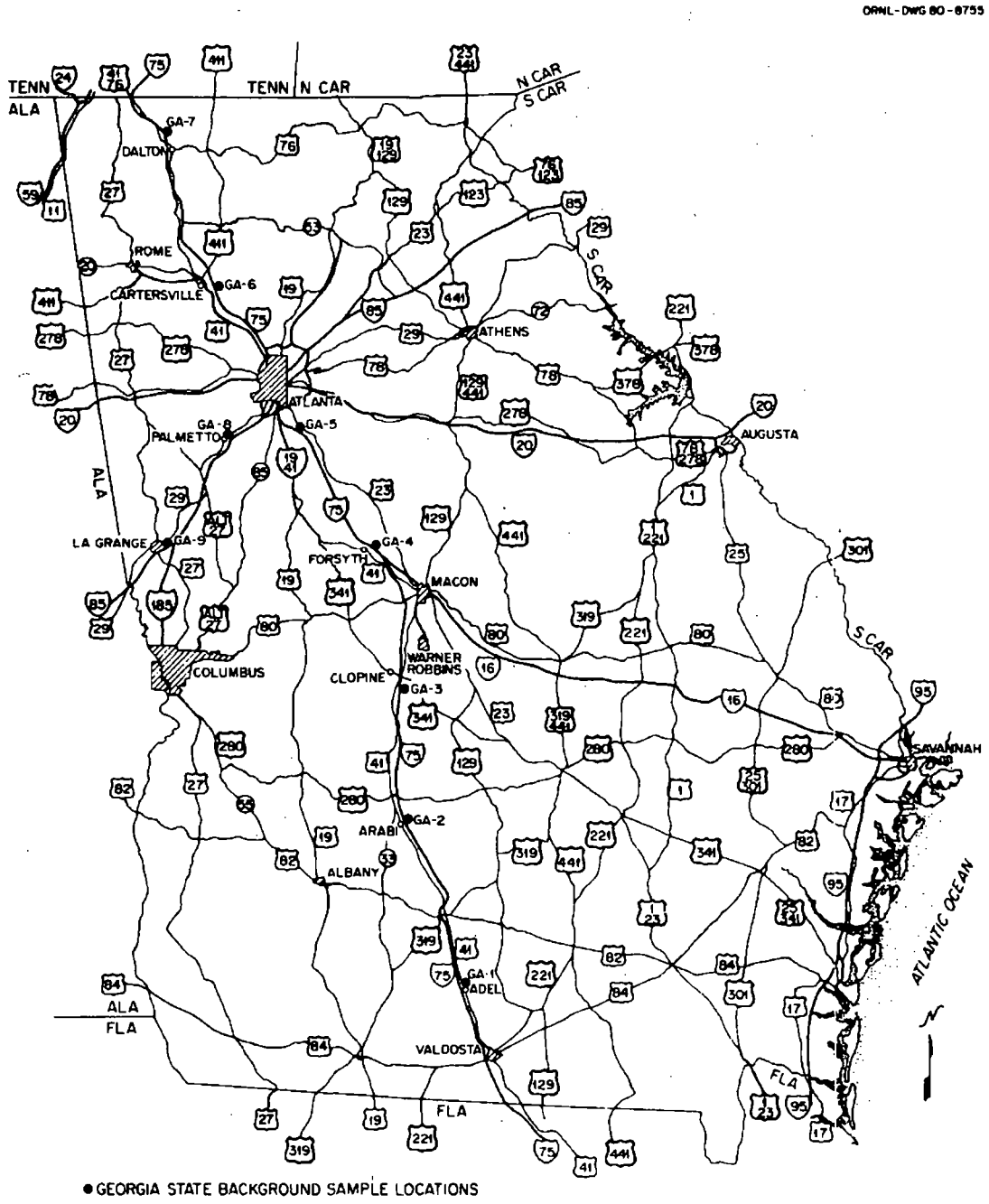

Fig. 10. Location of background samples and external gamma-ray exposure rate measurements in Georgia.

Table 10. Background radiation levels and nuclide concentrations in surface soil samples in the State of Idaho

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
ID-1	S side of I-80N, ~6.4 km E of the Idaho-Oregon border	13	[c]	1.3 ± 0.10	0.79
ID-2	Approx. 16 km E of Boise, Idaho picnic area, between Hwy 21 and Boise River	12	1.0 ± 0.18	1.1 ± 0.16	1.0
ID-3	E side of Hwy 21 at Idaho City, Idaho, city limit	12	0.96 ± 0.12	1.2 ± 0.12	0.80
ID-4	Rest area in Boise National Forest, ~60 km N of Lowman, Idaho	16	1.3 ± 0.06	1.9 ± 1.0	2.2
ID-5	S side of Hwy 21, ~1.6 km W of Stanley, Idaho	15	1.6 ± 0.24	1.6 ± 0.06	1.9
ID-6	Intersection of Hwys 55 and 52, N side of Horse Shoe Bend, Idaho	11	0.64 ± 0.02	1.0 ± 0.04	0.66
ID-7	E side of Hwy 55, S side of Smiths Ferry, Idaho	12	0.94 ± 0.04	1.2 ± 0.08	1.5
ID-8	S side of road, just S of Crouch, Idaho	13	1.4 ± 0.08	1.6 ± 0.10	1.3
ID-9	Sawtooth National Recreation Area, W side Hwy 93 across from Smiley Creek Air Strip	11	0.86 ± 0.04	0.88 ± 0.06	0.99
ID-10	Between airport and Hwy 93 in Hailey, Idaho	11	1.2 ± 0.06	0.42 ± 0.08	1.1
ID-11	NW corner of intersection of Hwys 25 and 93, E of Jerome, Idaho	13	1.1 ± 0.04	1.2 ± 0.06	0.98
ID-12	SW side of intersection of I-80N and I-15	11	0.94 ± 0.04	1.1 ± 0.04	0.90
ID-13	Idaho-Utah border on W side of I-80N	11	1.0 ± 0.06	0.94 ± 0.08	0.84

[a] Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b] Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

[c] Nuclide not found.

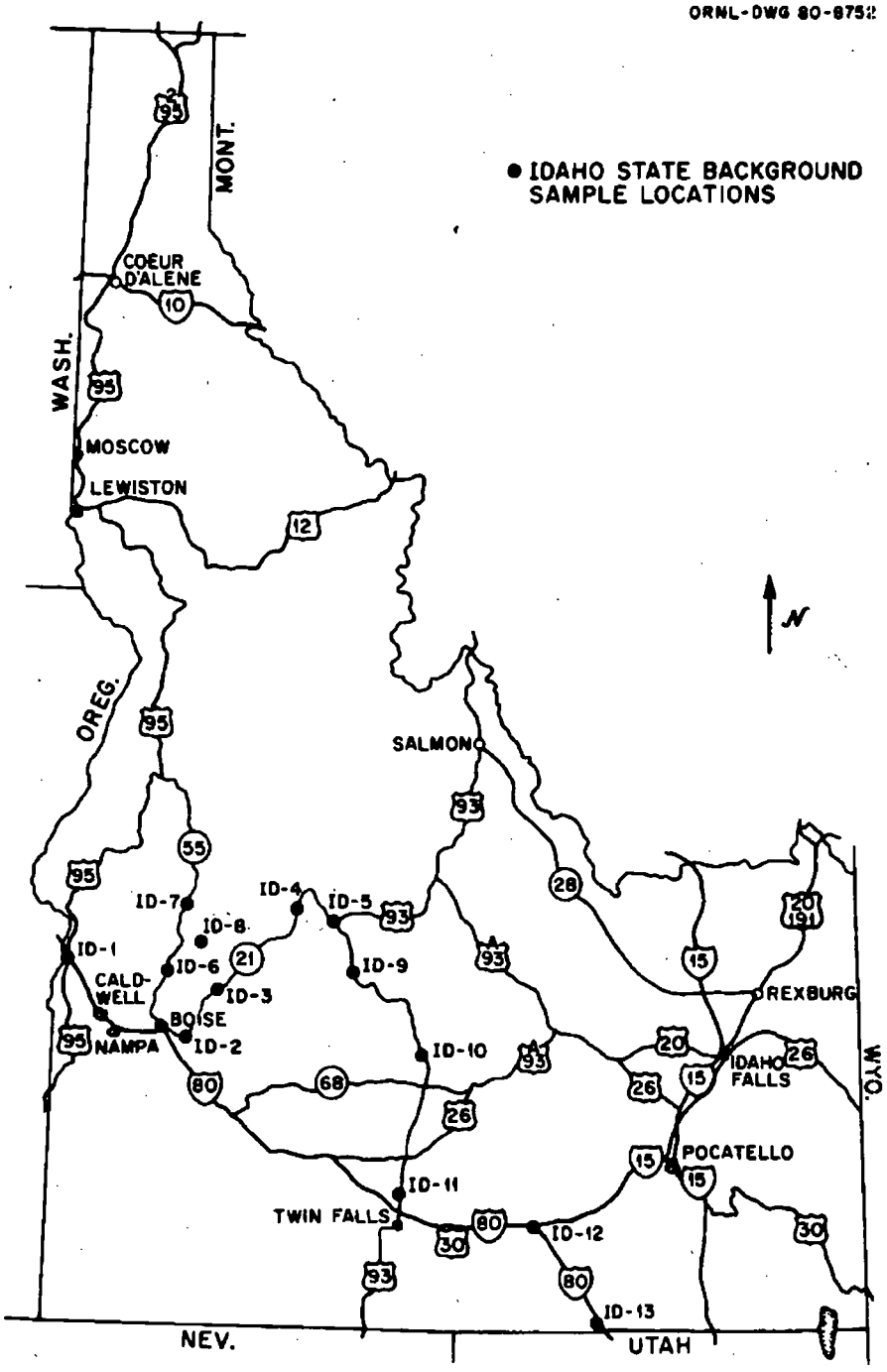

Fig. 11. Location of background samples and external gamma-ray exposure rate measurements in Idaho.

Table 11. Background radiation levels and nuclide concentrations in surface soil samples in the State of Illinois

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
IL-1	Approx. 1.6 km W of Albers exit, on S side of I-65	11	0.93 ± 0.06	1.1 ± 0.08	1.0
IL-2	SW corner of intersection of I-64 and Hwy 460, S of Mt. Vernon, Illinois	7.5	1.1 ± 0.10	1.1 ± 0.06	1.2
IL-3	S side of I-64, ~0.4 km E of intersection of I-64 and Hwy 1, near Illinois-Indiana border	7.2	0.82 ± 0.04	0.94 ± 0.12	0.87
IL-4	Approx. 1.9 km S of I-270 on Hwy 3 on W side of road	7.4	[c]	1.2 ± 0.06	1.1
IL-5	SW corner of intersection of Hwys 50, 3, and 158 near Columbia, Illinois	8.6	0.88 ± 0.04	1.0 ± 0.04	1.0
IL-6	W side of Hwy 3, on S side of Marys River, S of Chester, Illinois	7.3	1.2 ± 0.30	1.0 ± 0.06	1.2
IL-7	S side of Hwy 186, ~3.5 km E of Ware, Illinois	7.6	0.65 ± 0.08	0.49 ± 0.34	0.64
IL-8	Intersection of I-24 and Hwy 45, in NW corner	7.8	1.2 ± 0.10	0.81 ± 0.56	1.4

[a]Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b]Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

[c]Nuclide not found.

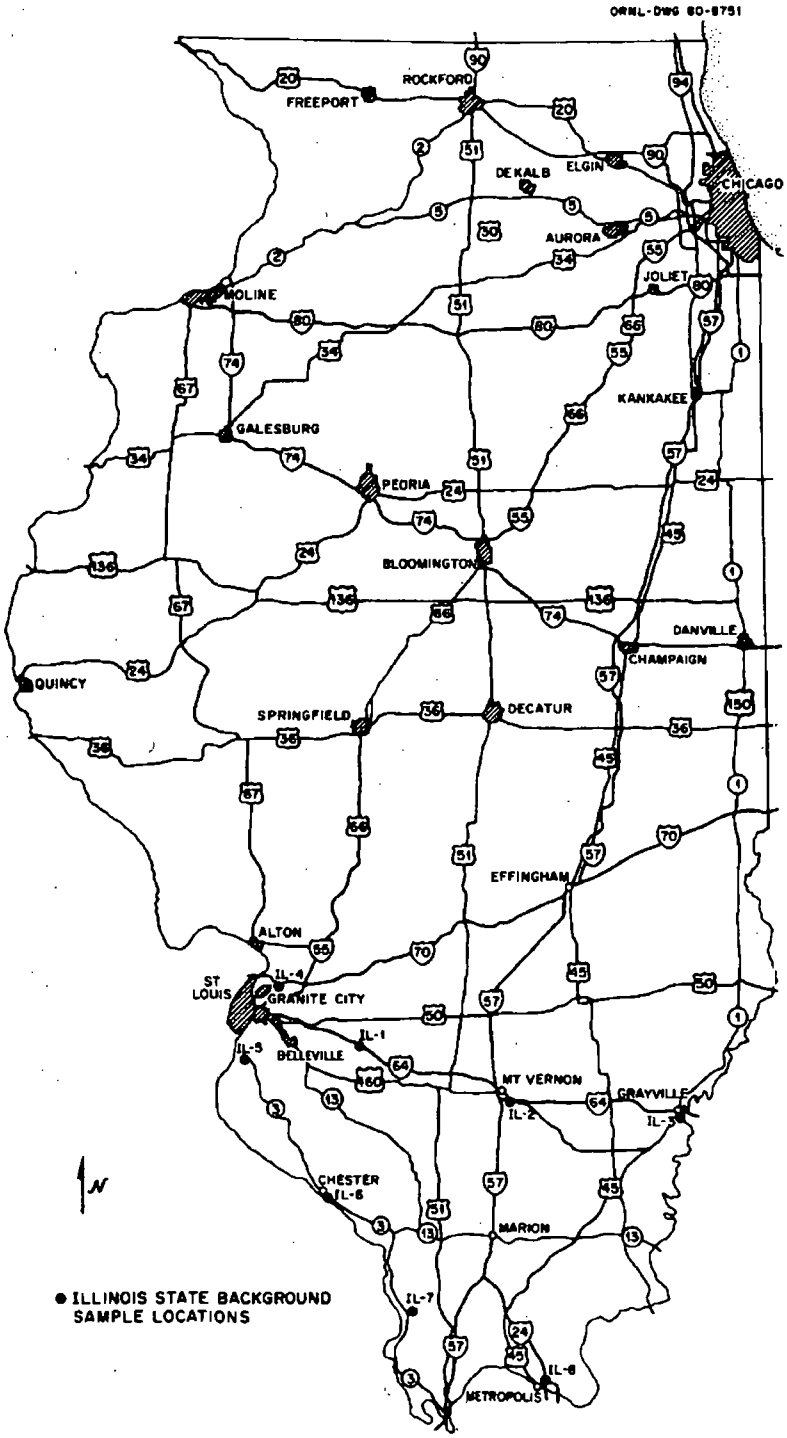

Fig. 12. Location of background samples and external gamma-ray exposure rate measurements in Illinois.

Table 12. Background radiation levels and nuclide concentrations in surface soil samples in the State of Indiana

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
IN-1	SE corner of intersection of I-64 and Hwy 161, in edge of woods	6.0	1.0 ± 0.08	1.1 ± 0.10	1.1
IN-2	SE corner of intersection of I-64 and Hwy 66, next to graveyard	7.1	1.1 ± 0.06	1.2 ± 0.08	1.4

[a]Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b]Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

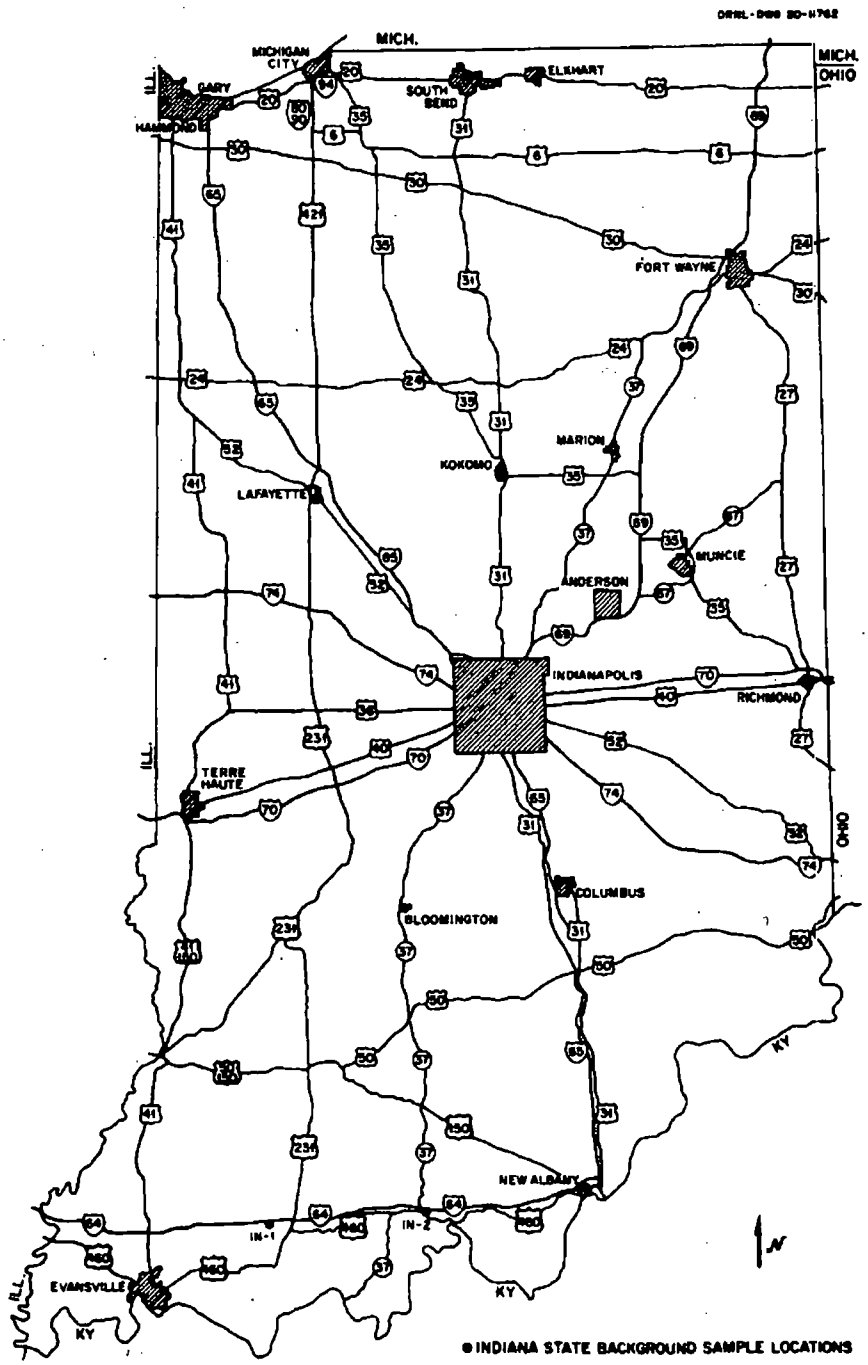

Fig. 13. Location of background samples and external gamma-ray exposure rate measurements in Indiana.

Table 13. Background radiation levels and nuclide concentrations in surface soil samples in the State of Kansas

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
KS-1	Approx. 550 m E of intersection of I-70 and Hwy 83-383, W of Oakley, Kansas	14	1.4 ± 0.12	[c]	1.2
KS-2	SW corner of intersection of I-70 and Hwy 283, W of Hays, Kansas	12	1.4 ± 0.10	1.6 ± 0.18	1.4
KS-3	In pasture behind rest stop on S side of I-70, approx. 3.2 km E of Hays, Kansas	10	1.0 ± 0.08	1.6 ± 0.08	1.1
KS-4	In field behind rest stop on S side of I-70, ~1.1 km W of intersection with Hwy 156	6.6	0.57 ± 0.04	0.32 ± 0.08	0.58
KS-5	Rest area on S side of I-70, ~1.4 km W of intersection with Hwy 77	8.2	0.34 ± 0.50	[c]	0.82
KS-6	S side of I-70, ~0.5 km W of intersection with Hwy 4	9.8	1.1 ± 0.54	1.5 ± 0.90	1.4

[a] Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b] Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

[c] Nuclide not found.

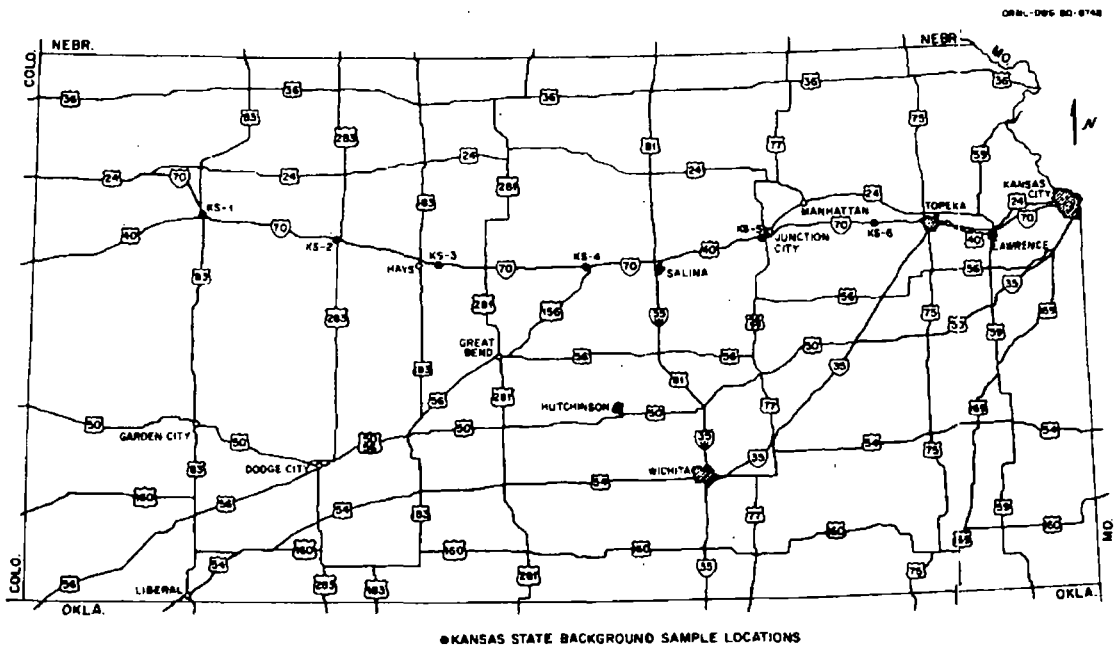

Fig. 14. Location of background samples and external gamma-ray exposure rate measurements in Kansas.

Table 14. Background radiation levels and nuclide concentrations in surface soil samples in the State of Kentucky

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
KY-1	Rest area on S side of I-64, ~38 km E of Louisville, Kentucky	7.1	1.0 ± 0.06	1.5 ± 0.10	1.3
KY-2	Rest area on S side of I-64, ~1.6 km E of intersection with Hwy 60	7.1	1.5 ± 0.14	1.1 ± 0.56	1.5
KY-3	W side of I-75, ~8 km S of Richmond, Kentucky, at S end of rest area	9.9	1.5 ± 0.12	1.2 ± 0.60	1.5
KY-4	NW corner of intersection of I-75 and Hwy 80, N of London, Kentucky	10	1.3 ± 0.04	1.5 ± 0.08	1.4
KY-5	N side of Hwy 62, ~0.5 km E of the intersection with Hwy 68, near Daffenville, Kentucky	6.9	1.0 ± 0.04	1.2 ± 0.08	1.3
KY-6	S side of Western Kentucky Parkway, ~0.3 km E of Hwy 109 intersection, near Charleston, Kentucky	3.9	1.2 ± 0.12	[c]	1.3
KY-7	S side of Western Kentucky Parkway, ~0.3 km E of Hwy 231 intersection S of Beaver Dam, Kentucky	6.2	1.1 ± 0.06	1.2 ± 0.08	1.3
KY-8	SE corner of intersection of I-65 and Hwy 31W, E of Bowling Green, Kentucky	4.3	1.6 ± 0.08	1.4 ± 0.08	1.4
KY-9	Intersection of Hwys 90 and 163, E of Summer Shade, Kentucky, SW corner of intersection	4.8	1.5 ± 0.08	0.88 ± 0.08	1.3
KY-10	N side of Hwy 95 (I-24), at intersection with Hwy 68, SE of Paducah, Kentucky	[d]	1.4 ± 0.06	1.2 ± 0.10	1.7
KY-11	Approx. 2.4 km E of Grayson, Kentucky, rest stop on N side of I-64	7.7	0.81 ± 0.06	1.0 ± 0.14	1.1
KY-12	Approx. 13 km W of Mt. Sterling, Kentucky, SE corner of intersection of I-64 and Hwy 60	9.3	1.2 ± 0.06	1.5 ± 0.14	1.7
KY-13	S side of I-64, ~1.6 km E of Hwy 32 at Morehead, Kentucky	11	4.2 ± 0.18	1.2 ± 0.04	3.8

[a] Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b] Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

[c] Nuclide not found.

[d] No data obtained.

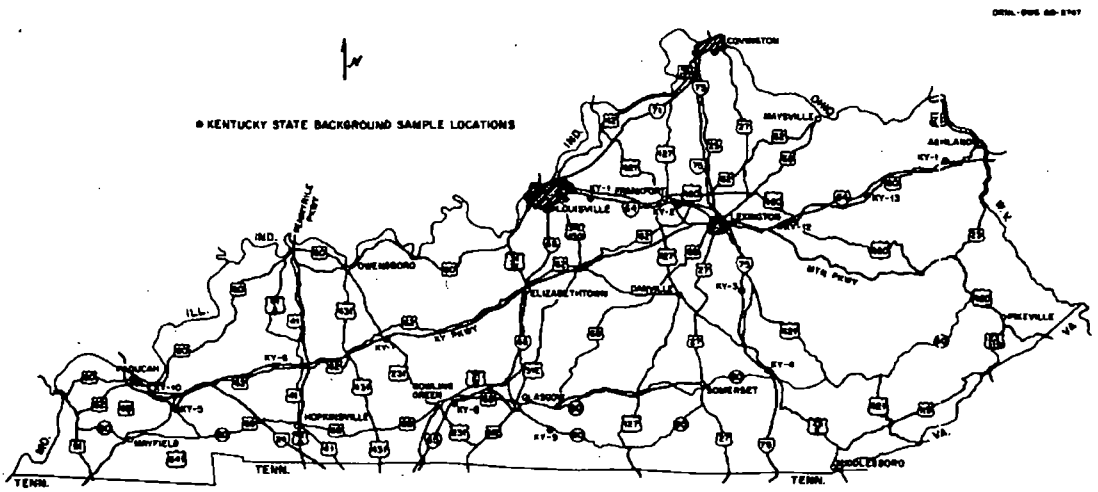

Fig. 15. Location of background samples and external gamma-ray exposure rate measurements in Kentucky.

Table 15. Background radiation levels and nuclide concentrations in surface soil samples in the State of Louisiana

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
LA-1	S side of Hwy 80, just N of I-20 at Bossier City, Louisiana	6.0	0.84 ± 0.04	0.72 ± 0.04	0.81
LA-2	S side of Hwy 136, ~0.8 km W of intersection with Hwy 149, 0.8 km N of I-20 near Ruston, Louisiana	5.7	[c]	[c]	0.48
LA-3	N side of Hwy 603 at intersection with Hwy 65, ~4 km S of I-20 near Tallulah, Louisiana	3.5	0.58 ± 0.04	0.60 ± 0.04	0.44

[a] Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b] Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

[c] Nuclide not found.

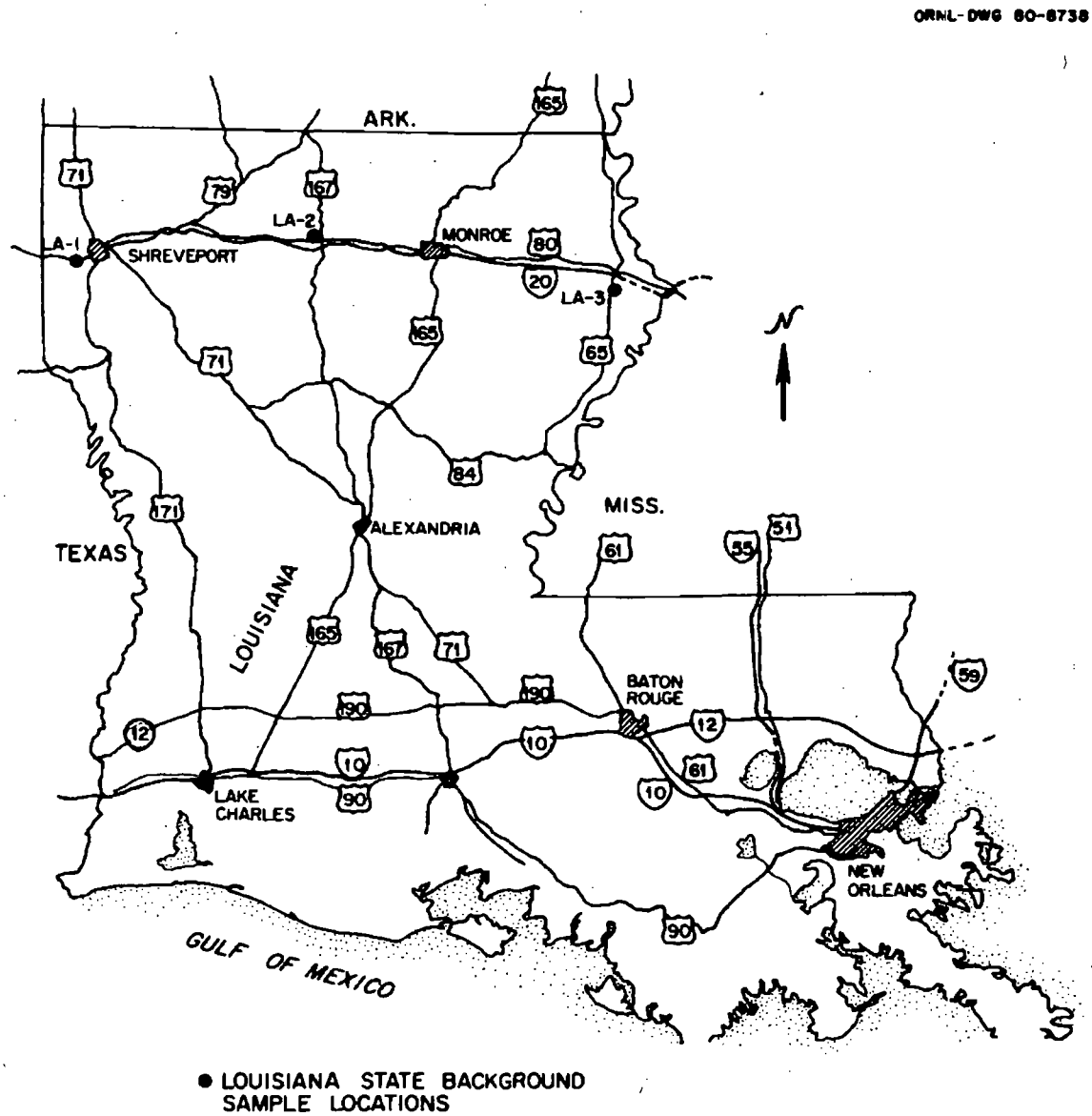

Fig. 16. Location of background samples and external gamma-ray exposure rate measurements in Louisiana.

Table 16. Background radiation levels and nuclide concentrations in surface soil samples in the State of Maryland

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
MD-1	SW corner of intersection of Hwys 50 and 197, ~20 km E of Washington, D. C.	6.3	0.77 ± 0.04	0.67 ± 0.04	0.93
MD-2	E side of Hwy 301, ~0.5 km N of intersection with Hwy 305, E of Centerville, Maryland	7.4	0.70 ± 0.04	0.70 ± 0.06	0.85
MD-3	N side of JFK Turnpike at intersection with Hwy 272	5.8	0.58 ± 0.06	0.85 ± 0.10	0.66
MD-4	SW corner of intersection of I-95 and I-695 in SW Baltimore, Maryland	4.5	0.49 ± 0.08	0.48 ± 0.02	0.54
MD-5	W side of Hwy 15, S of entrance to Cunningham Falls State Park	8.8	1.2 ± 0.06	0.86 ± 0.10	0.91
MD-6	Approx. 0.8 km S of Accident, Maryland, on W side of Hwy 219	[c]	0.59 ± 0.04	0.63 ± 0.04	0.80

[a]Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b]Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

[c]No data obtained.

Table 17. Background radiation levels and nuclide concentrations in surface soil samples in the State of Michigan

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
MI-1	E side of Hwy 23 at the Michigan-Ohio border, just N of Toledo, Ohio	c	0.99 ± 0.10	0.54 ± 0.04	0.78
MI-2	N of Hwy 71, just E of Corunna, Michigan	c	0.79 ± 0.08	0.76 ± 0.02	0.65
MI-3	W side of Gratiot County road, ~3.2 km SW of Edgewood, Michigan, next to Bad Creek	c	0.46 ± 0.04	0.24 ± 0.04	0.34
MI-4	Approx. 2 km E of Mt. Pleasant, Michigan, on S side of Hwy 20 in Isabella Indian Reservation	c	0.51 ± 0.02	0.39 ± 0.02	0.49
MI-5	Approx. 2 km S of Midland, Michigan, on Midland County road between Midland and Poseyville, Michigan	c	0.69 ± 0.06	0.51 ± 0.02	0.50
MI-6	Approx. 11 km of St. Johns, Michigan, on W side of road at intersection with county road	c	0.86 ± 0.10	0.66 ± 0.12	0.57
MI-7	Approx. 6.4 km E of Adrian, Michigan, at the intersection of Deerfield Rd and Wellsville Hwy	c	2.0 ± 0.12	0.41 ± 0.28	1.0
MI-8	Approx. 6 km N of Adrian, Michigan, at the intersection of Shepard Rd. and Bent Oak Hwy	c	1.5 ± 0.12	0.82 ± 0.08	1.1
MI-9	S side of Hwy 223, ~11 km W of Adrian, Michigan	c	1.5 ± 2.0	0.69 ± 0.04	1.2
MI-10	Approx. 1.6 km E of Hwy 52, on E. Gorman Rd., about 8 km S of Adrian, Michigan	c	1.2 ± 0.14	0.54 ± 0.12	0.70

[a]Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b]Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

[c]No data obtained.

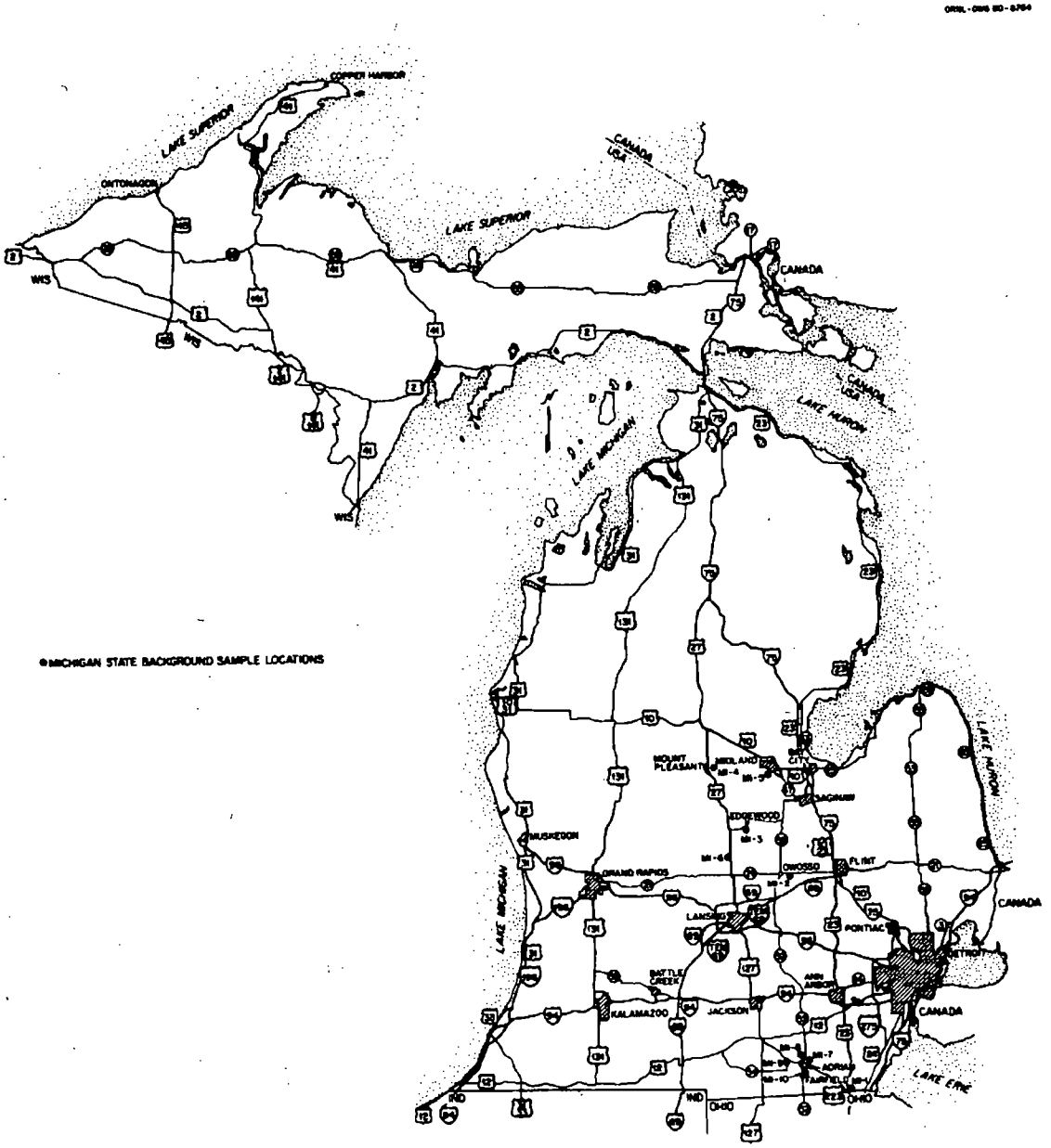

Fig. 17. Location of background samples and external gamma-ray exposure rate measurements in Michigan.

Table 18. Background radiation levels and nuclide concentrations in surface soil samples in the State of Mississippi

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
MIS-1	Rest stop ~10 km E of Vicksburg, Mississippi, on S side of I-20, mile marker 6.5	11	1.3 ± 0.30	0.85 ± 0.10	0.69
MIS-2	Behind Ramada Inn at intersection of Hwy 35 and I-20, near Forest, Mississippi, in wooded area	4.3	1.6 ± 0.10	1.7 ± 0.40	1.7
MIS-3	S side of I-20, ~19 km W of Mississippi-Alabama border, at Russel exit	8.7	0.77 ± 0.02	0.81 ± 0.04	0.81

[a]Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b]Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

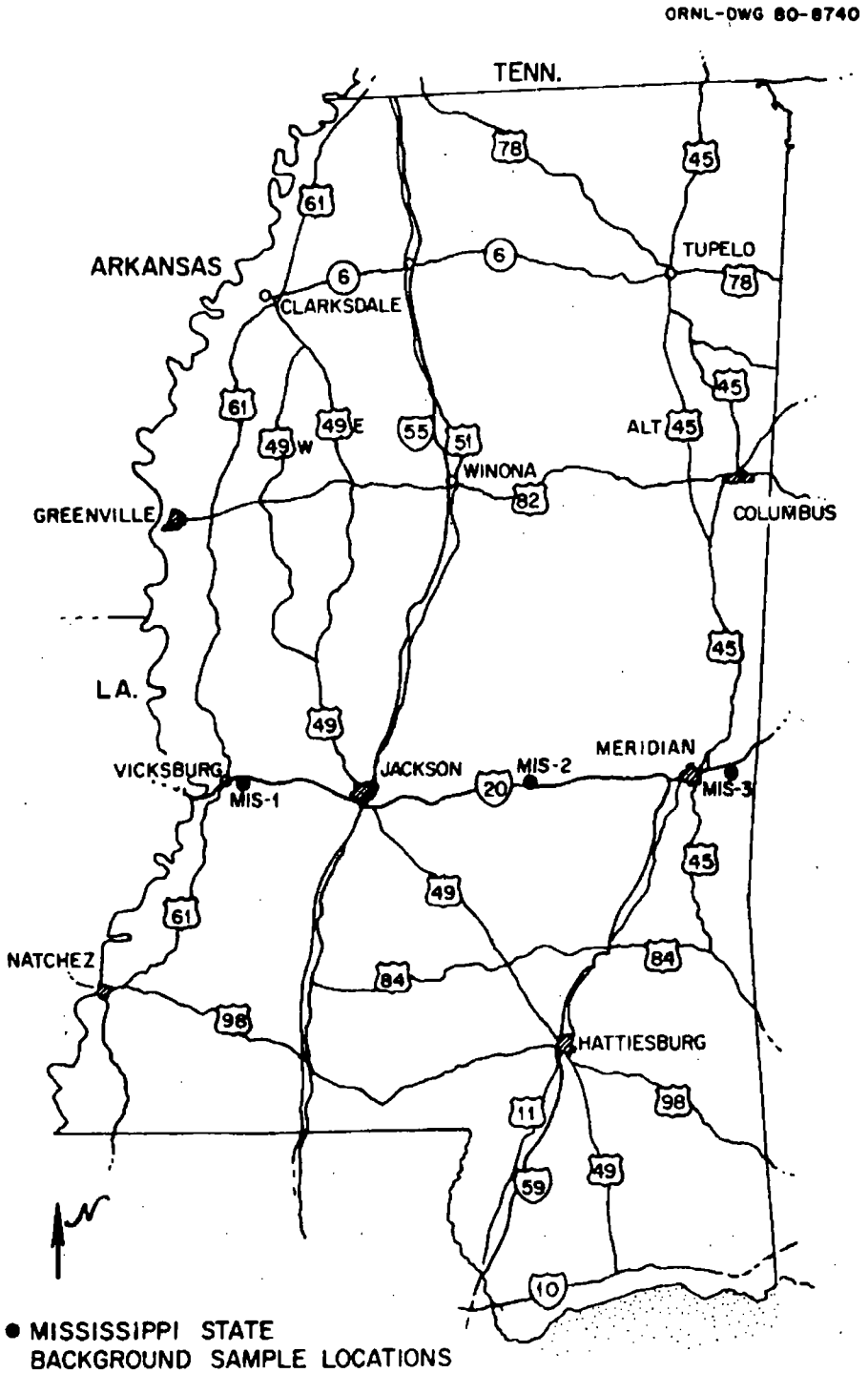

Fig. 18. Location of background samples and external gamma-ray exposure rate measurements in Mississippi.

Table 19. Background radiation levels and nuclide concentrations in surface soil samples in the State of Missouri

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
MO-1	Approx. 45 km E of Kansas City, Missouri, in pasture field on S side of I-70	6.0	1.4 ± 0.04	1.3 ± 0.10	1.7
MO-2	Approx. 140 km E of Kansas City, Missouri, at intersection of I-70 and exit J, SE corner	10	1.3 ± 0.06	1.2 ± 0.10	1.3
MO-3	Rest stop on S side of I-70, ~16 km E of Williamsburg, Missouri	6.7	1.1 ± 0.06	1.0 ± 0.08	1.2
MO-4	SE corner of intersection of Hwy 175 and I-70 in O'Fallon, Missouri	7.5	1.3 ± 0.08	1.1 ± 0.12	1.1
MO-5	Approx. 34 km N of Missouri-Arkansas border, on E side of I-55, mile marker 21	8.1	1.2 ± 0.04	1.2 ± 0.06	1.3
MO-6	E side of I-55, ~14 km N of intersection with Hwy Alt. 61, at mile marker 76	5.4	0.31 ± 0.04	0.32 ± 0.04	0.33
MO-7	E side of I-55, ~1.6 km S of Appleton exit, E of Friedheim, Missouri	7.6	1.1 ± 0.06	1.1 ± 0.06	1.1
MO-8	Exit 0 off I-55, near Bloomsdale, Missouri	6.8	0.83 ± 0.04	0.76 ± 0.06	0.81
MO-9	E side of I-55, ~0.4 km S of Hwy 141 intersection, Maxville, Missouri	5.1	1.1 ± 0.06	1.1 ± 0.06	1.1
MO-10	W side of Hwy 367, ~0.3 km S of intersection with Hwy 67, N of St. Louis, Missouri	4.6	1.0 ± 0.10	0.95 ± 0.14	0.76

[a]Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b]Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

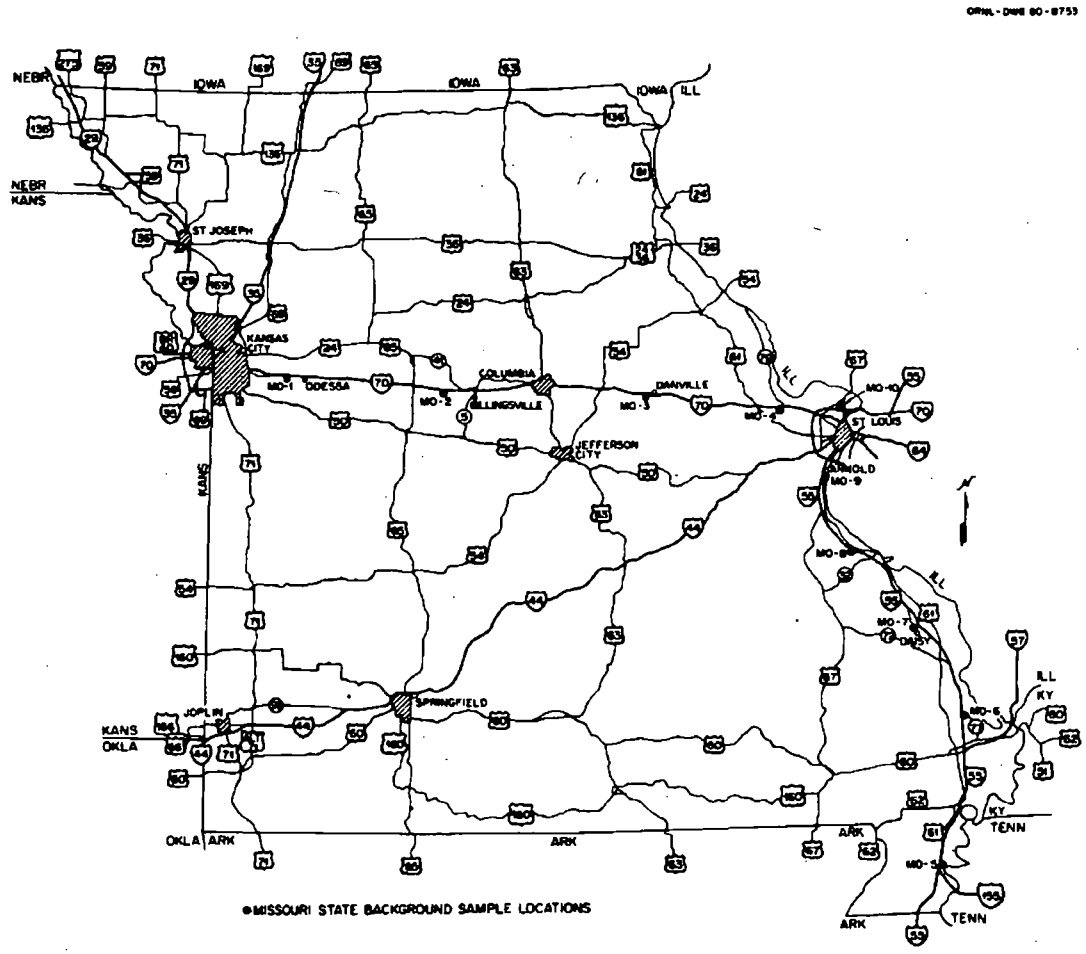

Fig. 19. Location of background samples and external gamma-ray exposure rate measurements in Missouri.

Table 20. Background radiation levels and nuclide concentrations in surface soil samples in the State of Nevada

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
NV-1	Approx. 4.8 km W of Nevada-Utah border, S side of Hwy 40	19	1.7 ± 0.10	3.0 ± 0.14	1.8
NV-2	N side of I-80, ~270 m E of Death, Nevada, exit	14	2.0 ± 0.14	1.4 ± 0.18	1.3
NV-3	Rest stop on N side of I-80, ~1.6 km W of Hwy 21	12	1.6 ± 0.06	1.4 ± 0.08	1.4
NV-4	N side of Hwy 40, ~5 km E of Winnemucca, Nevada	15	1.4 ± 0.06	1.4 ± 0.08	1.3
NV-5	Junction of Hwys 95 and 140, NW corner, ~50 km N of Winnemucca, Nevada	12	1.5 ± 0.06	1.2 ± 0.08	1.3
NV-6	Approx. 180 m W of Hwy 140 junction at Denio, Nevada	11	0.89 ± 0.12	0.62 ± 0.14	0.74

[a]Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b]Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

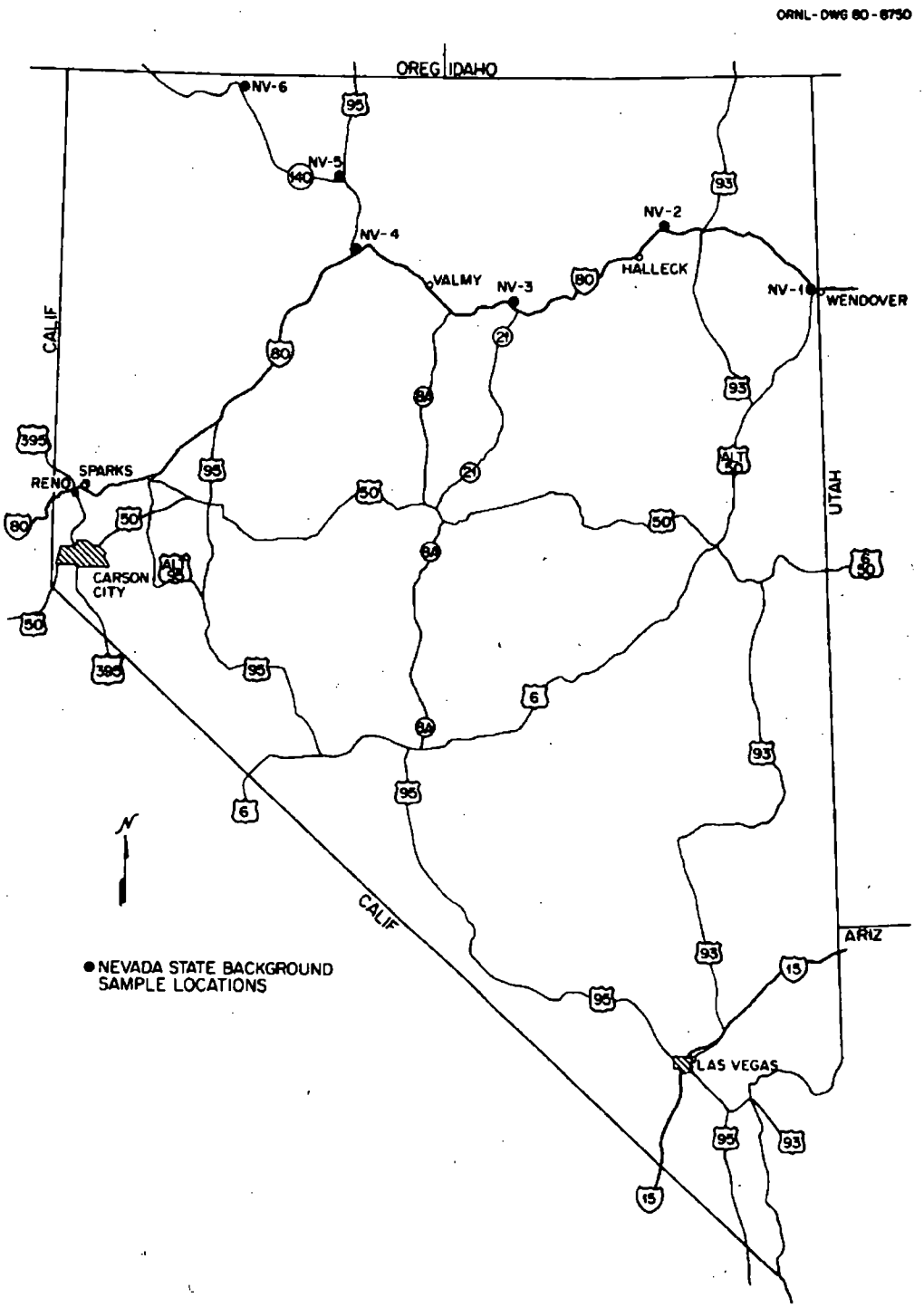

Fig. 20. Location of background samples and external gamma-ray exposure rate measurements in Nevada.

Table 21. Background radiation levels and nuclide concentrations in surface soil samples in the State of New Jersey

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
NJ-1	Fort Mott, New Jersey, ~30 m from Deleware River	2.3	0.31 ± 0.06	0.33 ± 0.06	0.31
NJ-2	W side of Plant Rd., between I-295 and Hwy 130 in Deepwater, New Jersey	5.5	0.79 ± 0.06	0.87 ± 0.06	0.99
NJ-3	S side of Hwy 49, ~3.7 km S of Bridgeton, New Jersey	7.4	0.96 ± 0.16	0.84 ± 0.06	0.64
NJ-4	S side of Hwy 40, just W of Hwy 50 junction, NW of Belcoville, New Jersey	2.8	0.24 ± 0.02	c	0.13
NJ-5	N side of Hwy 40, between Hwy 47 and 55, just W of Malaga, New Jersey	4.2	0.28 ± 0.02	0.31 ± 0.02	0.35
NJ-6	SE corner of intersection of I-295 and Hwy 70, near Cherry Hill, New Jersey	6.1	1.1 ± 0.14	0.95 ± 0.10	0.96
NJ-7	S side of Hwy 70, just E of its intersection with Hwy 72 near Lebanon State Forest	3.1	0.45 ± 0.10	0.31 ± 0.06	0.42
NJ-8	E side of Hwy 9, ~1.6 km N of its intersection with Hwy 70, S of Lake Wood, New Jersey	4.3	0.52 ± 0.06	0.50 ± 0.04	0.68
NJ-9	Intersection of Hwys 9 and 18, SE corner, ~1.6 km S of Sagre Woods South, New Jersey	4.7	0.59 ± 0.04	0.66 ± 0.04	0.46
NJ-10	Intersection of I-195 and Hwy 130, NE corner, ~5 km N of Yardville, New Jersey	6.2	0.93 ± 0.04	0.80 ± 0.10	1.0
NJ-11	E side of Hwy 1, in SE corner of intersection with Hwy 18, near Highland Park, New Jersey	8.3	1.1 ± 0.08	0.90 ± 0.44	1.1
NJ-12	N side of I-287, between Hwys 1 and 27, S of Metuchen, New Jersey	6.0	1.3 ± 0.24	0.85 ± 0.16	0.97
NJ-13	N side of I-287, E of Randolphville Rd. exit, S of Piscataway, New Jersey	3.4	0.55 ± 0.06	0.53 ± 0.04	0.50
NJ-14	W side of Hwy 18, ~3.2 km S of I-287, N of New Brunswick, New Jersey	6.5	0.81 ± 0.04	1.1 ± 0.06	1.0

Table 21. (continued)

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
NJ-15	SE corner of intersection of I-287 and Hwy 28, W of Bound Brook, New Jersey	6.8	1.0 ± 0.10	1.0 ± 0.10	1.2
NJ-16	S side of Hwy 22, ~16 km E of intersection with I-287	6.8	0.95 ± 0.06	1.1 ± 0.06	1.2
NJ-17	NW corner of intersection of I-78 and Hwy 531, ~1.6 km N of Watchung, New Jersey	6.3	1.2 ± 0.14	1.1 ± 0.14	1.2
NJ-18	NE corner of intersection of I-78 and I-287, near Pluckeman, New Jersey	5.1	0.78 ± 0.06	1.2 ± 0.06	0.70
NJ-19	NE corner of intersection of I-78 and Hwy 523, ~3.2 km S of Oldwick, New Jersey	9.5	1.2 ± 0.06	1.5 ± 0.06	1.2
NJ-20	Approx. 9.6 km W of Somerville, New Jersey, on S side of Hwy 22	7.3	1.3 ± 0.06	1.2 ± 0.86	1.2
NJ-21	N side of Hwy 202, ~180 m S of Mills Rd, W of Raritan, New Jersey	13	0.90 ± 0.06	1.2 ± 0.08	1.4
NJ-22	E side of Hwy 206, ~280 m S of Hwy 513 and Chester, New Jersey	5.6	1.4 ± 0.10	0.95 ± 0.06	1.0
NJ-23	NW corner of intersection of I-80 and Hwy 517, at Allamuchy, New Jersey	9.1	0.92 ± 0.04	0.89 ± 0.04	0.85
NJ-24	NW corner of intersection of Hwy 22 and I-287, W of Bound Brook, New Jersey	[d]	1.2 ± 0.30	1.5 ± 0.10	1.3

[a] Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b] Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

[c] Nuclide not found.

[d] No data obtained.

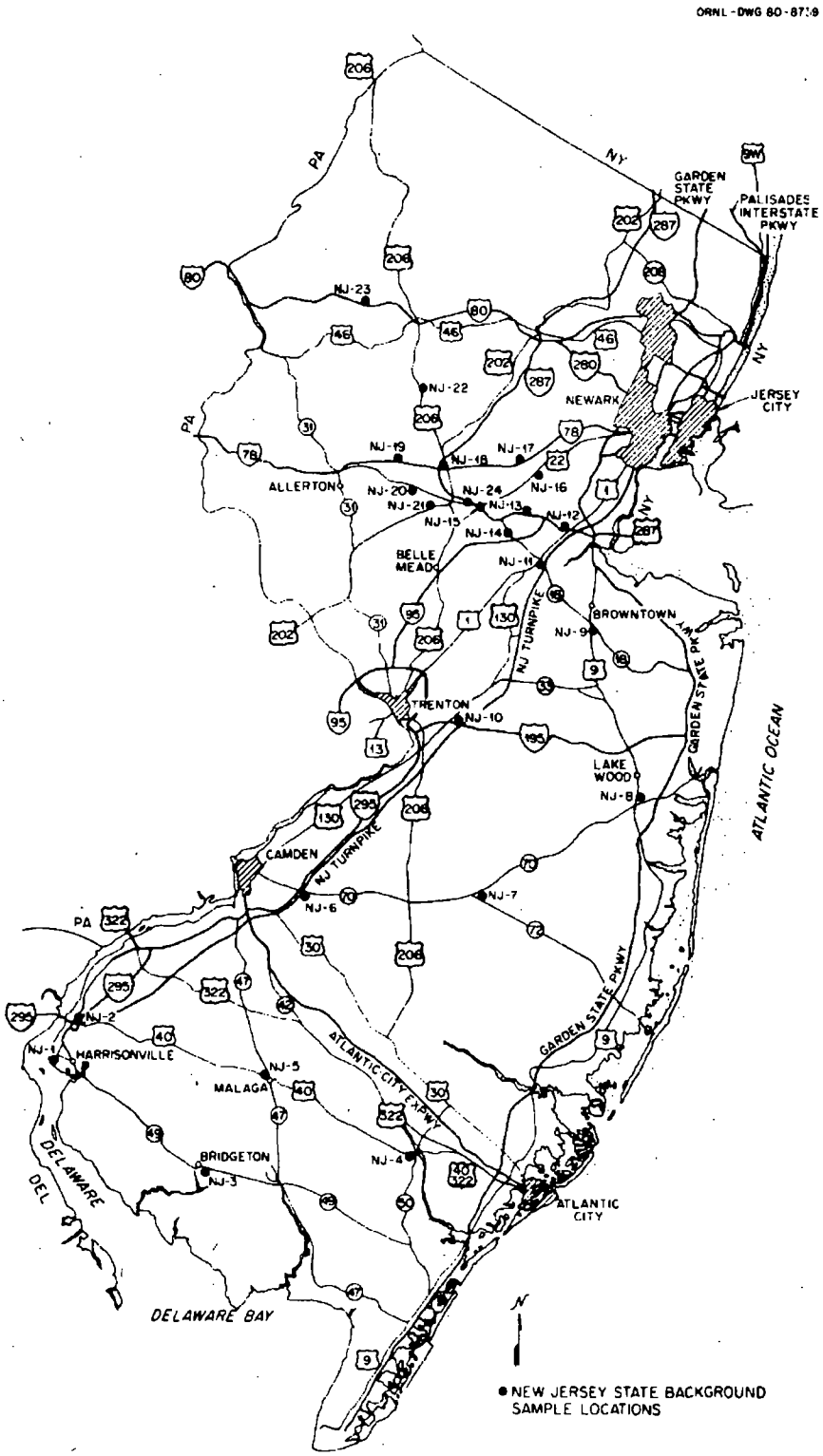

Fig. 21. Location of background samples and external gamma-ray exposure rate measurements in New Jersey.

Table 22. Background radiation levels and nuclide concentrations in surface soil samples in the State of New Mexico

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
NM-1	Approx. 0.8 km E of Red Rock Trading Post, N side of road at Arizona-New Mexico border	8.7	1.6 ± 0.10	0.48 ± 0.10	0.53
NM-2	Intersection of roads at Beautiful Mountain, overlooking Sanostee, New Mexico	16	2.7 ± 0.20	1.8 ± 0.22	1.5
NM-3	SW side of intersection of Hwy 666 and road to Sanostee, New Mexico	10	1.4 ± 0.10	0.87 ± 0.08	0.96
NM-4	Intersection of Farmington Rd and Navajo Mine Rd, ~9.6 km N of Bitsi, New Mexico	9.5	2.1 ± 0.12	0.98 ± 0.14	1.2
NM-5	Intersection of La Vida Mission Rd, Farmington Rd, and Hwy 7, ~42 km S of Farmington, New Mexico	11	1.4 ± 0.12	0.86 ± 0.12	0.91
NM-6	Approx. 1.6 km S of San Juan River, SW of Farmington, New Mexico, W side of Hwy	8.4	1.4 ± 0.10	1.0 ± 0.06	0.91
NM-7	W side of Hwy 170, at the Colorado-New Mexico border, N of LaPlata, New Mexico	9.9	2.0 ± 0.16	1.3 ± 0.14	1.3
NM-8	New Mexico-Colorado border, E side of Hwy 666, N of Shiprock, New Mexico	7.9	2.0 ± 0.12	1.1 ± 0.10	1.5
NM-9	Arizona-New Mexico border, N side of Hwy 504, W of Beclabito, New Mexico	6.8	1.3 ± 0.10	0.48 ± 0.70	0.93
NM-10	SW corner of intersection of I-40 and Hwy 66, just E of Grants, New Mexico	7.2	1.0 ± 0.04	0.54 ± 0.06	0.99
NM-11	W side of Hwy 53, ~14 km S of I-40 and Grants, New Mexico	11	1.2 ± 0.06	0.78 ± 0.06	1.1
NM-12	Approx. 4.8 km E of San Mateo in Cibola National Forest	15	0.72 ± 0.08	0.86 ± 0.08	0.83
NM-13	Approx. 3.2 km N of Gallup, New Mexico, E side of Hwy 666 at RR crossing	8.9	1.1 ± 0.06	1.3 ± 0.10	1.3

[a]Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b]Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

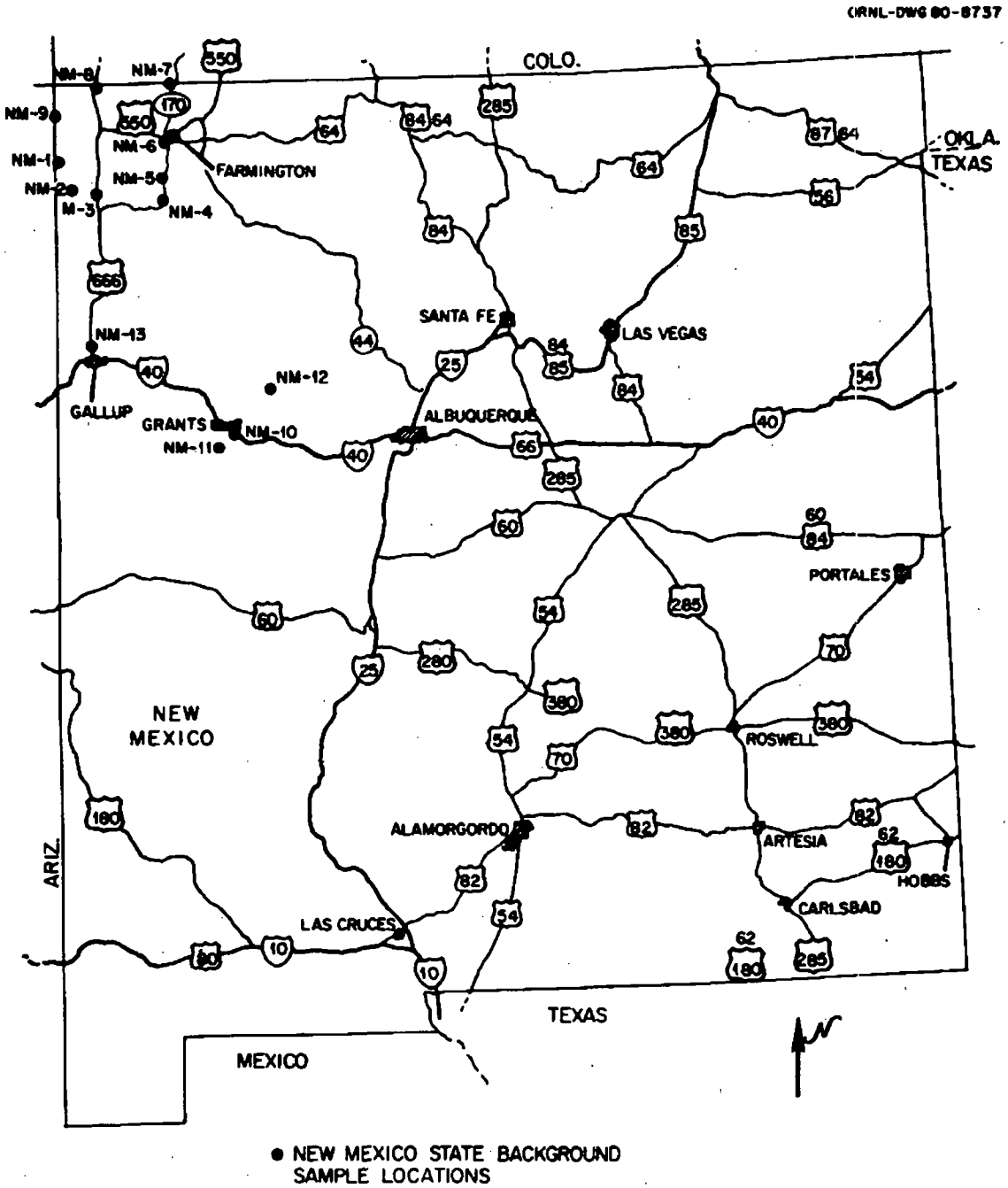

Fig. 22. Location of background samples and external gamma-ray exposure rate measurements in New Mexico.

Table 23. Background radiation levels and nuclide concentrations in surface soil samples in the State of New York

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
NY-1	City of Tonawanda, New York, at city limit on River Rd., across from Consolidated Freightways Terminal	[c]	0.97 ± 0.08	0.65 ± 0.06	0.99
NY-2	W side of road connecting Hwys 77 and 31, ~4.8 km E of Lockport, New York	[c]	0.48 ± 0.04	0.46 ± 0.04	0.97
NY-3	W side of River Rd., Tonawanda, New York, across from Allied Chemical Corp.	[c]	1.2 ± 0.04	0.88 ± 0.06	1.2
NY-4	Intersection of Tonawanda Creek Rd. and Niagara Falls Blvd. in North Tonawanda, New York	[c]	0.69 ± 0.04	0.40 ± 0.12	0.76
NY-5	Approx. 0.8 km S of Simonds Saw and Steel Company on E side of Hwy in Lockport, New York	[c]	0.74 ± 0.06	0.79 ± 0.06	0.85
NY-6	Approx. 9 km S of Lockport, New York, on W side of Hwy 78	[c]	1.0 ± 0.04	1.1 ± 0.06	0.96

[a] Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b] Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

[c] No data obtained.

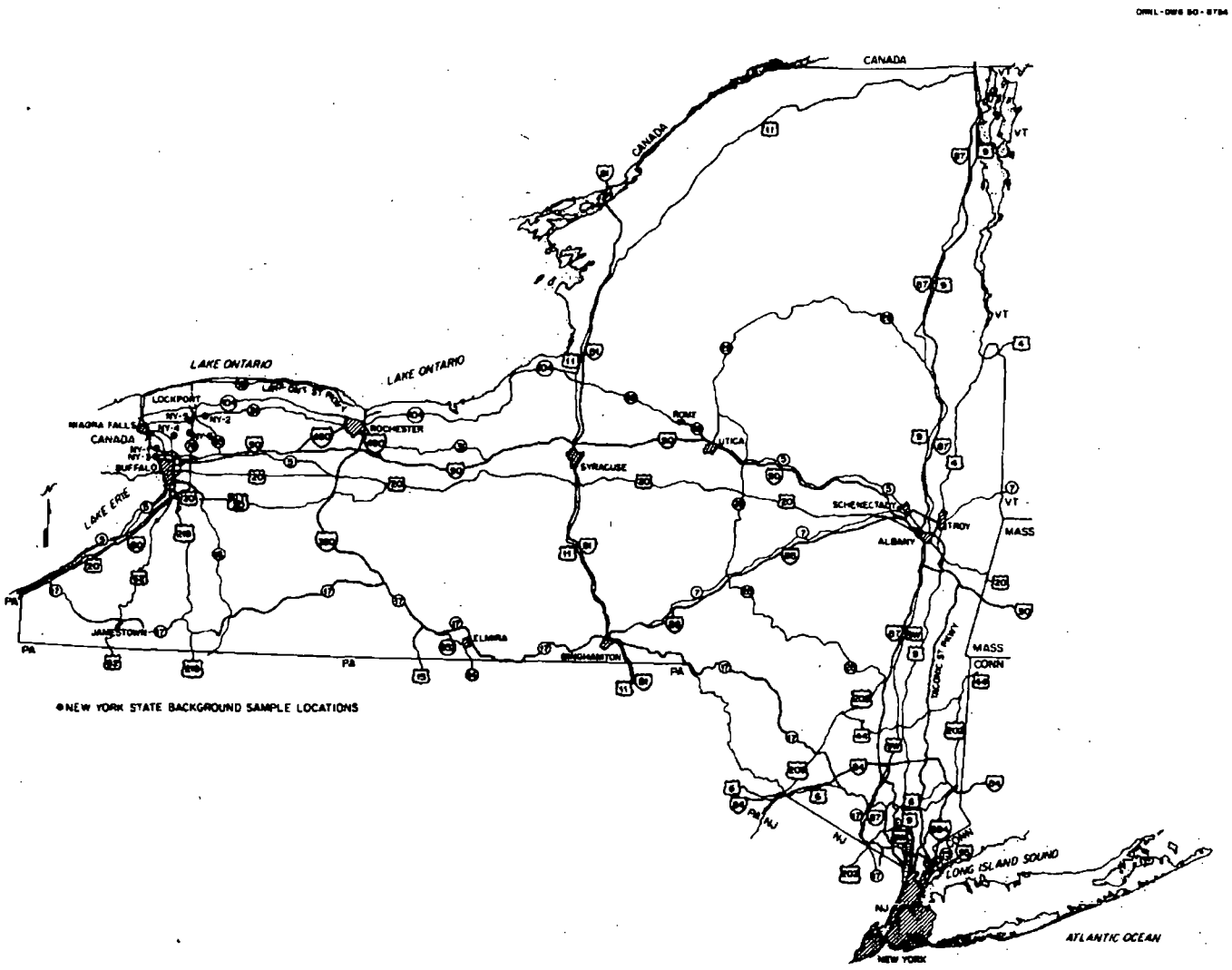

Fig. 23. Location of background samples and external gamma-ray exposure rate measurements in New York.

Table 24. Background radiation levels and nuclide concentrations in surface soil samples in the State of North Carolina

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
NC-1	North Carolina-Virginia border on W side of I-85, ~9.6 km N of Norlina, North Carolina	7.3	0.53 ± 0.06	0.42 ± 0.02	0.65
NC-2	Approx. 21 km N of Durham, North Carolina, at intersection of I-85 and Hwy 15	12	0.77 ± 0.02	1.5 ± 0.14	0.91
NC-3	Approx. 16 km W of Greensboro, North Carolina, in NE corner of intersection of I-85 and Hwy 61	3.2	0.48 ± 0.08	0.51 ± 0.06	0.73
NC-4	NE corner of intersection of I-40 and Hwy 801, W of Winston-Salem, North Carolina	4.9	0.58 ± 0.02	0.53 ± 0.04	0.73
NC-5	N side of I-40, ~2.4 km W of Conover, North Carolina	7.0	0.78 ± 0.04	0.91 ± 0.06	0.90
NC-6	Rest area on N side of I-40, ~4.8 km E of Marion, North Carolina	9.5	1.2 ± 0.06	1.0 ± 0.06	1.6
NC-7	NE corner of intersection of I-40 and Hwy 215, W of Ashville, North Carolina	9.0	0.95 ± 0.04	1.5 ± 0.10	1.1
NC-8	Rest stop N side of I-40, at Tennessee-North Carolina border	13	0.92 ± 0.34	1.0 ± 0.36	0.39

[a]Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b]Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

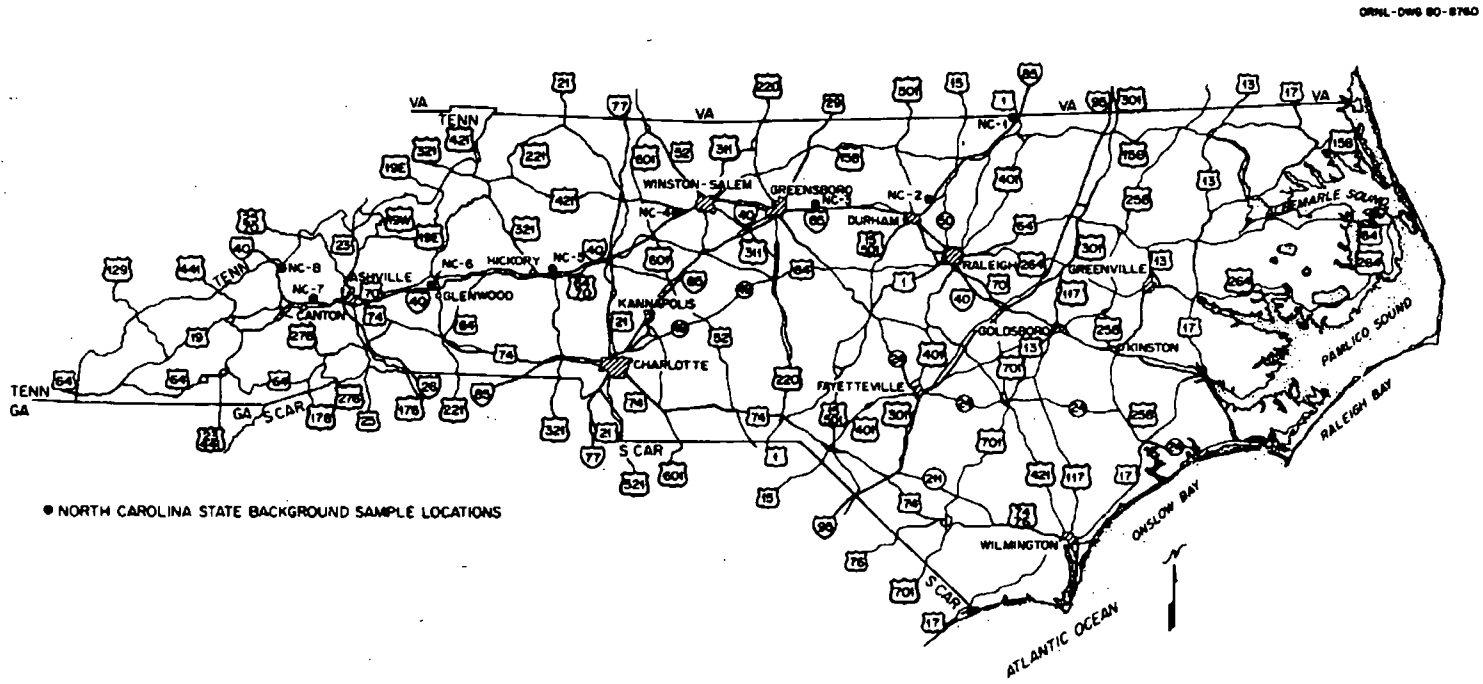

Fig. 24. Location of background samples and external gamma-ray exposure rate measurements in North Carolina.

Table 25. Background radiation levels and nuclide concentrations in surface soil samples in the State of Ohio

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
OH-1	Rest area on S side of I-71, ~16 km S of Columbus, Ohio, at mile marker 92	9.2	2.5 ± 0.16	0.71 ± 0.02	2.2
OH-2	Approx. 51 km N of Columbus, Ohio, at rest stop on S side of I-71	7.1	1.5 ± 0.12	0.74 ± 0.60	1.3
OH-3	Approx. 21 km E of Wickliffe, Ohio, at rest stop on S side of I-90	9.2	1.1 ± 0.04	1.1 ± 0.10	1.2
OH-4	Approx. 8 km S of I-70, at intersection of Hwy 13 and 188, near Thornville, Ohio	[c]	2.0 ± 0.14	1.0 ± 0.16	1.7
OH-5	SE corner of intersection of I-77 and Hwy 821, at Macksburg, Ohio	11	1.3 ± 0.12	1.5 ± 0.20	1.6
OH-6	Rest area on E side of I-77, ~16 km S of I-70, near Buffalo, Ohio	8.2	1.9 ± 0.16	1.1 ± 0.24	1.6
OH-7	SW corner of intersection of I-70 and Hwy 9, S of St. Clairsville, Ohio	8.5	1.5 ± 0.16	1.5 ± 0.18	1.7
OH-8	W side of I-475, between Hwys 20 and 2, in W Toledo, Ohio	5.1	0.81 ± 0.04	0.80 ± 0.02	0.76
OH-9	Rest stop on W side of I-75, just S of Findlay, Ohio	4.9	1.3 ± 0.08	0.93 ± 0.06	1.2
OH-10	W side of I-75, just S of Hwy 67 exit, E of Wapakoneta, Ohio	4.8	1.5 ± 0.06	1.0 ± 0.06	1.4
OH-11	W side of I-75, ~0.4 km N of intersection with Hwy 571, near Tipp City, Ohio	2.8	1.2 ± 0.04	0.99 ± 0.06	0.96
OH-12	W side of I-75, just N of intersection with Hwy 122, E of Middletown, Ohio	4.8	1.0 ± 0.04	0.98 ± 0.04	0.86

[a] Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b] Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

[c] No data obtained.

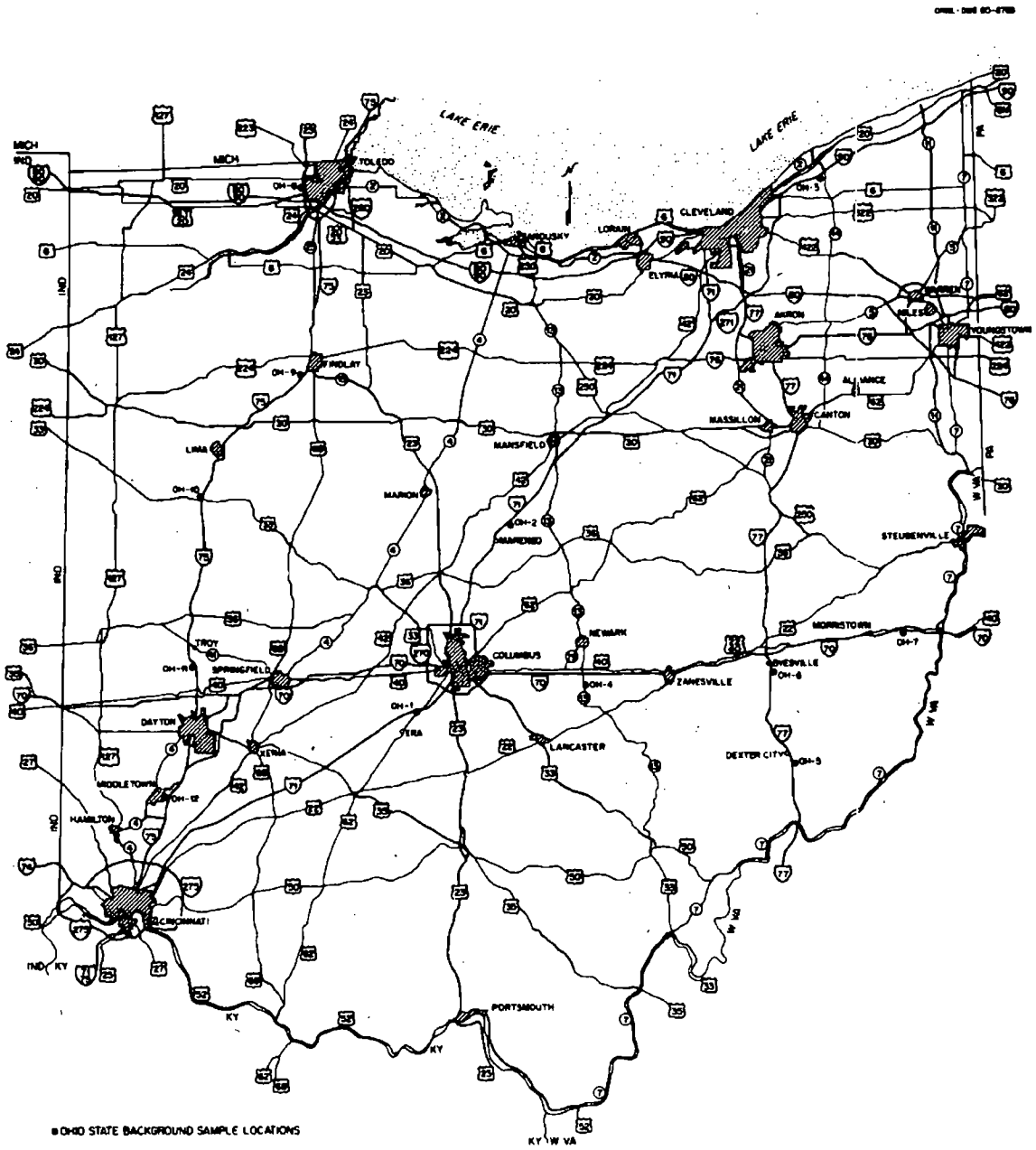

Fig. 25. Location of background samples and external gamma-ray exposure rate measurements in Ohio.

Table 26. Background radiation levels and nuclide concentrations in surface soil samples in the State of Oregon

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
OR-1	NE side of Hwy 140 at Oregon-Nevada border	19	2.1 ± 0.08	1.5 ± 0.12	2.0
OR-2	N side of Hwy 140, ~1.6 km W of Adel, Oregon	10	0.24 ± 0.30	0.46 ± 0.04	0.55
OR-3	Approx. 0.8 km N of Oregon-California border, on W side of Goose Lake, W side of road	13	[c]	0.69 ± 0.06	0.70
OR-4	S side of Hwy 140, ~1.6 km W of Quartz Mts., Oregon	8.3	0.40 ± 0.08	0.43 ± 0.04	0.50
OR-5	Intersection of Hwys 395 and 31 at Valley Falls, Oregon, N side of Y	9.7	0.61 ± 0.10	0.55 ± 0.02	0.57
OR-6	N side of Hwy 31, at W end of Paisley, Oregon	9.5	0.82 ± 0.04	0.74 ± 0.06	0.86
OR-7	Across from Wagontire, Oregon, on E side of Hwy 395	10	0.81 ± 0.04	0.68 ± 0.04	0.78
OR-8	Approx. 8 km E of Burns, Oregon, on S side of Hwy 20	12	0.95 ± 0.08	0.94 ± 0.70	1.0
OR-9	S side of Hwy 20, at W city limits of Juntura, Oregon	8.2	0.62 ± 0.12	0.46 ± 0.06	0.59

[a] Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b] Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

[c] No data obtained.

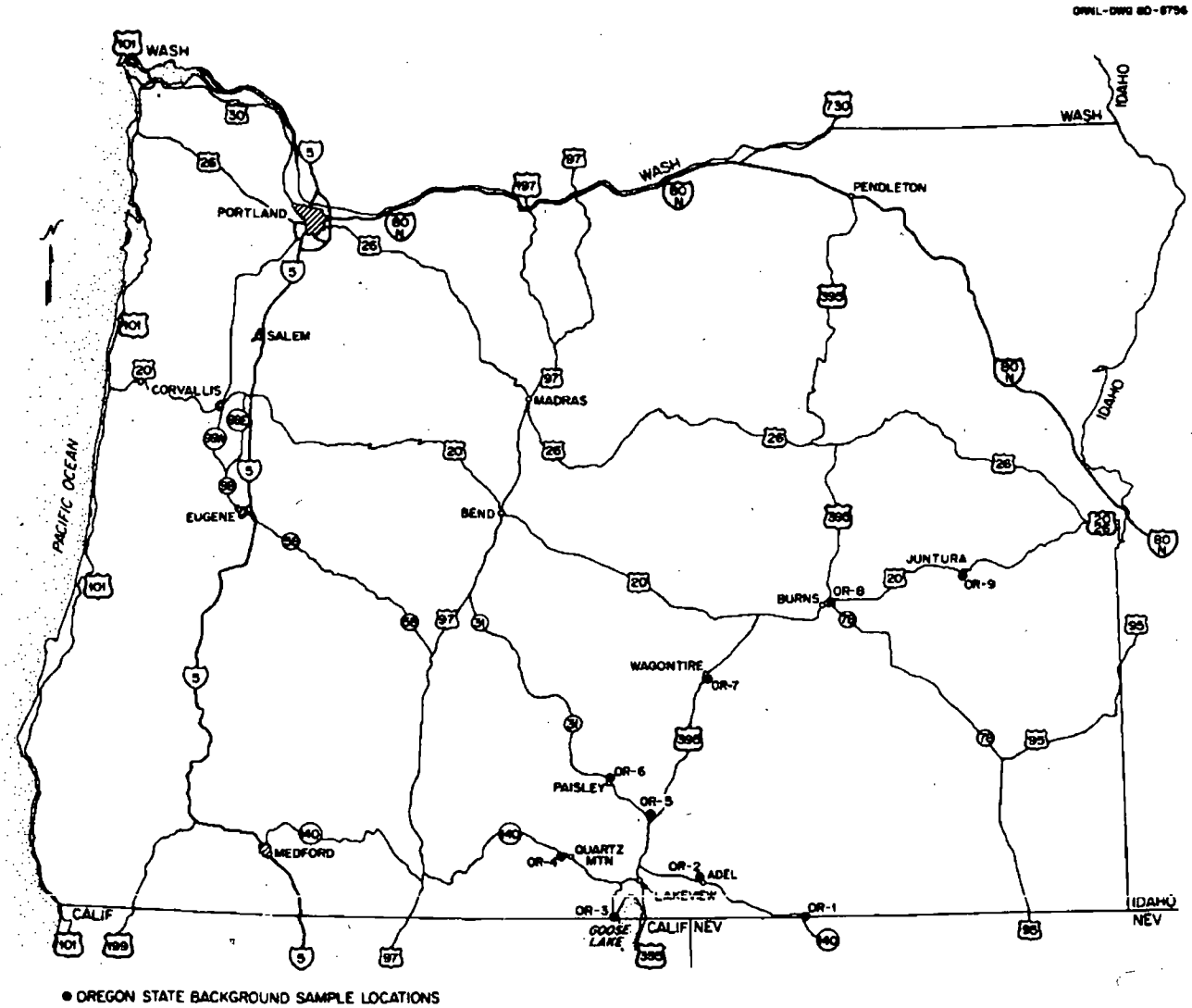

Fig. 26. Location of background samples and external gamma-ray exposure rate measurements in Oregon.

Table 27. Background radiation levels and nuclide concentrations in surface soil samples in the State of Pennsylvania

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
PA-1	Rest area at Pennsylvania-Ohio border on I-90, W of Erie, Pennsylvania	5.2	0.46 ± 0.04	0.38 ± 0.02	0.41
PA-2	W side of I-79, ~3.2 km S of intersection with Hwy 6-19, near Kerrtown, Pennsylvania	c	1.1 ± 0.12	1.0 ± 0.06	1.1
PA-3	Along Hwy 40 at Glyde, Pennsylvania	6.8	1.2 ± 0.08	1.4 ± 0.08	1.4
PA-4	Along Hwy 40 at Chalkhill, Pennsylvania	2.5	1.4 ± 0.06	1.2 ± 0.08	1.3
PA-5	Along Hwy 40 at Addison, Pennsylvania	3.2	1.2 ± 0.06	0.99 ± 0.06	1.1
PA-6	Along Hwy 18, ~1.6 km N of Hickory, Pennsylvania	5.6	1.6 ± 0.06	1.7 ± 0.08	1.5
PA-7	Approx. 2.4 km N of Burgettstown, Pennsylvania, along Hwy 18	4.9	1.7 ± 0.12	0.72 ± 0.36	1.4
PA-8	Along Hwy 18, at Frankfort Springs, Pennsylvania	4.5	1.2 ± 0.08	1.4 ± 0.08	1.3
PA-9	Along Hwy 18, at Shippingport, Pennsylvania	3.1	1.3 ± 0.14	1.3 ± 0.10	1.3
PA-10	S side of Hwy 519, between I-79 and Hwy 19, near Strabane, Pennsylvania	7.6	0.84 ± 0.04	1.3 ± 0.08	1.2
PA-11	NE side of Hwy 980 at intersection with I-79, near Cannonsburg, Pennsylvania	5.7	1.4 ± 0.14	1.3 ± 0.02	1.5
PA-12	At Pennsylvania-West Virginia border, on W side of I-79, near Mt. Morris, Pennsylvania	5.5	0.83 ± 0.04	0.88 ± 0.06	1.0
PA-13	E city limits of Cannonsburg, Pennsylvania, on Hwy 980	8.3	1.0 ± 0.08	1.1 ± 0.08	1.3
PA-14	Bank of Linden Creek, ~3.2 km E of Hwy 19, on Hwy 519, near Cannonsburg, Pennsylvania	6.7	0.76 ± 0.04	1.0 ± 0.06	1.1
PA-15	N side of Linden Rd., along Linden Creek, ~8 km E of Hwy 19, near Cannonsburg, Pennsylvania	7.4	1.4 ± 0.10	0.88 ± 0.64	1.5
PA-16	SW corner of intersection of I-70 and Hwy 31, near Wyano, Pennsylvania	6.9	0.99 ± 0.12	0.95 ± 0.12	0.97
PA-17	S side of Pennsylvania Turnpike (I-70-76), ~8 km W of Somerset, Pennsylvania	7.6	2.4 ± 0.12	1.0 ± 0.08	1.2
PA-18	S side of Pennsylvania Turnpike, ~8 km E of Earlston, Pennsylvania	6.6	0.96 ± 0.06	1.1 ± 0.08	1.2
PA-19	S side of Hwy 30 in Caledonia State Park, ~5.6 km E of Chambersburg, Pennsylvania	5.8	1.1 ± 0.22	0.95 ± 0.06	0.78

Table 27. (continued)

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
PA-20	Approx. 11 km N of Easton, Pennsylvania, on W side of Hwy 611	2.5	0.81 ± 0.10	0.69 ± 0.12	0.63
PA-21	Intersection of I-78 and Hwy 143, just N of Lenhartsville, Pennsylvania	8.1	0.96 ± 0.04	1.2 ± 0.04	1.0
PA-22	NW corner of intersection of I-81 and Hwy 443, near Hanover, Pennsylvania	7.3	0.85 ± 0.04	1.2 ± 0.08	1.1
PA-23	N side of Pennsylvania Turnpike, W side of exit 15, near the Blue Mtn. Tunnel	8.4	1.1 ± 0.06	1.1 ± 0.06	1.2
PA-24	E side of I-79 between Meadow Lands and Race Track exits, near McGovern, Pennsylvania	12	1.7 ± 0.06	1.4 ± 0.14	1.4
PA-25	Approx. 3.2 km NE of Cannonsburg Industrial Park, on E side of I-79, in Cannonsburg, Pennsylvania	9.4	1.4 ± 0.06	1.5 ± 0.08	1.4
PA-26	Approx 1.6 km N of Cannonsburg Industrial Park on Hwy 980	14	1.0 ± 0.04	1.2 ± 0.06	1.3
PA-27	NE of intersection of Hwys 422 and 28-66 at Kittanning, Pennsylvania	8.9	1.5 ± 0.08	1.5 ± 0.10	1.9
PA-28	W side of I-79, ~32 km N of Pittsburg, Pennsylvania, at Hwy 228 intersection	5.7	1.9 ± 0.20	1.3 ± 0.08	1.7
PA-29	Intersection of two secondary roads, E of Blairsville, Pennsylvania, at Toms Run Creek	8.7	1.3 ± 0.12	1.3 ± 0.10	1.1
PA-30	Secondary road ~1.3 km E of Strangford, Pennsylvania	5.1	0.72 ± 0.06	0.78 ± 0.06	0.78
PA-31	S side of Market St., E end of Blairsville, Pennsylvania, S of Hwy 22 near city limits	7.5	0.98 ± 0.08	1.0 ± 0.08	0.87
PA-32	E side of Hwy 217 S of Blairsville, Pennsylvania, near the Conemaugh River	8.9	1.1 ± 0.08	1.1 ± 0.10	1.1
PA-33	SW side of the township of Torrance, Pennsylvania	3.7	1.1 ± 0.20	0.89 ± 0.04	0.79

[a] Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b] Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

[c] No data obtained.

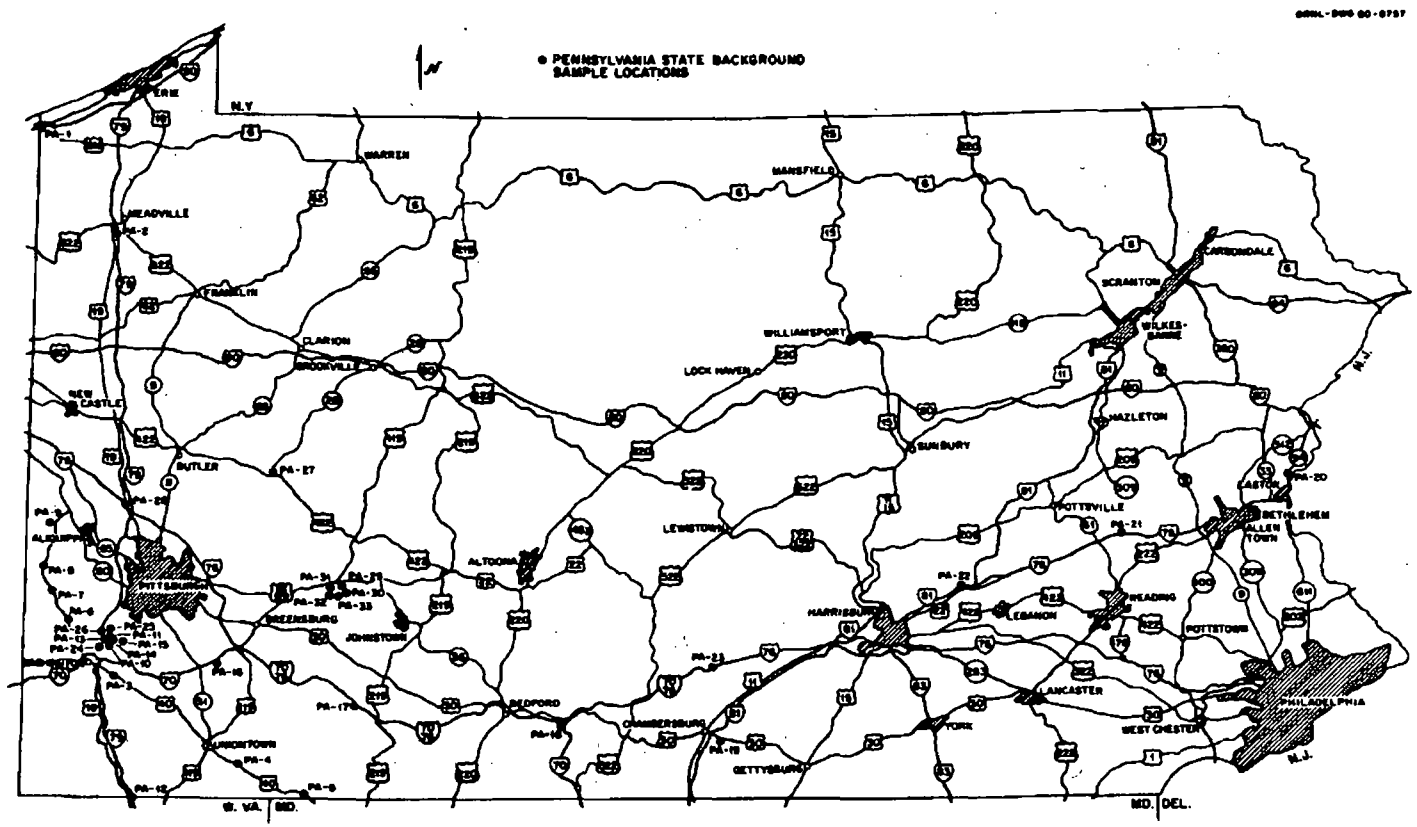

Fig. 27. Location of background samples and external gamma-ray exposure rate measurements in Pennsylvania.

Table 28. Background radiation levels and nuclide concentrations in surface soil samples in the State of Tennessee

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
TN-1	Welcome station at Tennessee-Kentucky border, W side of I-75 near Jellico, Tennessee	7.0	0.98 ± 0.12	0.83 ± 0.44	0.95
TN-2	SW side of I-75, ~0.8 km N of intersection with Hwy 61, at Norris, Tennessee	8.7	[c]	0.80 ± 0.06	0.91
TN-3	Approx. 6.4 km N of Crossville, Tennessee, at NW corner of intersection of I-40 and Hwy 127	6.9	0.72 ± 0.04	0.68 ± 0.06	0.72
TN-4	Rest stop ~32 km W of Cookeville, Tennessee, on N side of I-40	3.1	1.1 ± 0.06	1.1 ± 0.04	1.1
TN-5	N side of I-40, ~0.4 km W of intersection with Hwy 70, in E Nashville, Tennessee	6.3	1.3 ± 0.10	0.97 ± 0.14	1.3
TN-6	E side of Hwy 13, ~0.4 km N of I-70, near Buffalo, Tennessee	2.9	[d]	[d]	1.1
TN-7	W bank of Forked Deer River, on N side of I-40, ~1.3 km W of intersection with Hwy 20, NW of Jackson, Tennessee	6.3	0.65 ± 0.02	0.66 ± 0.04	0.77
TN-8	N side of I-40, ~0.8 km W of intersection with Hwy 64, E of Memphis, Tennessee	9.1	1.4 ± 0.14	1.1 ± 0.08	1.3
TN-9	Approx. 1 km S of Tennessee-Kentucky border, on W side of Hwy 127, near Chanute, Tennessee	4.3	0.95 ± 0.10	0.67 ± 0.08	0.98
TN-10	W side of Hwy 27, ~0.2 km S of intersection with Hwy 52, near Elgin, Tennessee	4.5	1.4 ± 0.08	1.5 ± 0.14	1.2
TN-11	Rest stop on S side of I-40, ~3.2 km W of intersection with I-81, near Dandridge, Tennessee	6.1	1.2 ± 0.04	1.0 ± 0.06	1.3
TN-12	E side of I-81, ~3.2 km N of intersection with Hwy 81, near Fall Branch, Tennessee	11	0.98 ± 0.10	1.1 ± 0.60	0.89

[a] Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b] Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

[c] Nuclide not found.

[d] No data obtained.

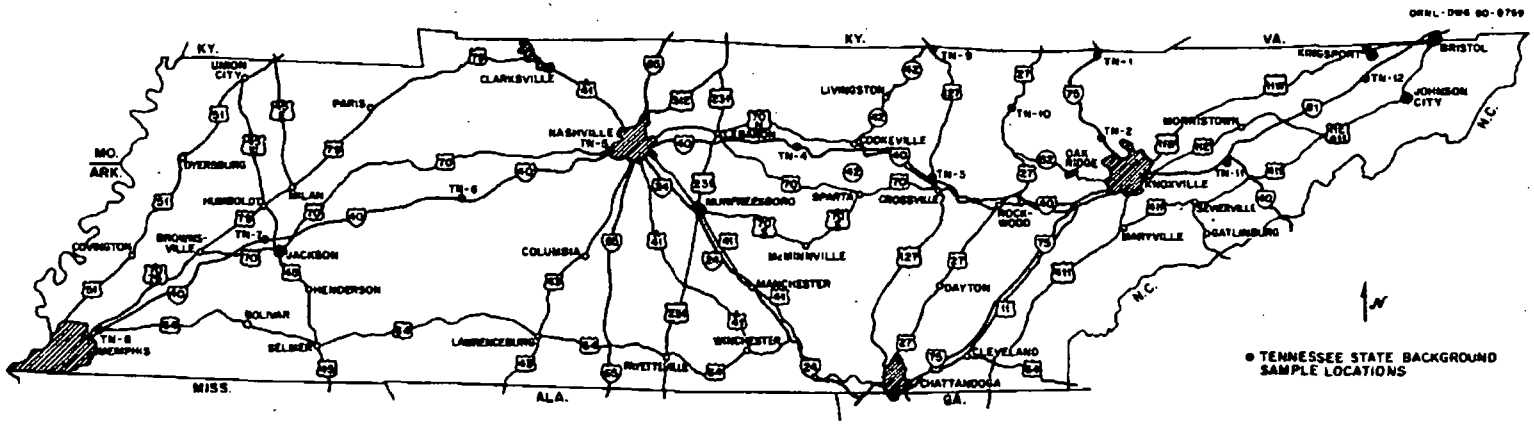

Fig. 28. Location of background samples and external gamma-ray exposure rate measurements in Tennessee.

Table 29. Background radiation levels and nuclide concentrations in surface soil samples in the State of Texas

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
TX-1	S side of Hwy 16, behind Holiday Inn in Kerrville, Texas	5.3	1.0 ± 0.08	0.47 ± 0.36	0.70
TX-2	E side of Hwy 59, at intersection with Hwy 239, ~3.2 km W of Goliad, Texas	2.5	0.88 ± 0.10	0.78 ± 0.14	0.68
TX-3	E of Beeville, Texas, at intersection of Hwys 59 and 181, W side of ramp to Hwy 181	2.3	0.54 ± 0.06	0.40 ± 0.12	0.56
TX-4	N side of Hwy 624, just W of intersection with Hwy 281, near Orange Grove, Texas	5.6	0.73 ± 0.12	0.85 ± 0.02	1.5
TX-5	E side of Hwy 16, at S city limit of Tilden, Texas	2.2	1.1 ± 0.08	0.83 ± 0.14	0.87
TX-6	Rest area on S side of Hwy 97, ~1.6 km E of Jourdanton, Texas	2.6	1.4 ± 0.30	1.1 ± 0.12	1.0
TX-7	S side of Hwy 87, just E of intersection with Hwy 97, near Stockdale, Texas	1.4	1.1 ± 0.10	0.84 ± 0.02	1.0
TX-8	Approx. 0.8 km W of Yorktown, Texas, at intersection of Hwys 72 and 2980, S side of Hwy 72	2.4	0.63 ± 0.06	0.76 ± 0.04	0.64
TX-9	S side of Hwy 942, ~1.6 km E of Hwy 59 and Leggett, Texas, in yard of Prarie Jones Baptist Church	3.2	0.57 ± 0.04	0.67 ± 0.04	0.48
TX-10	Rest area on E side of Hwy 59, ~8 km S of Garrison, Texas	5.2	0.93 ± 0.26	0.58 ± 0.12	0.74

[a] Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b] Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

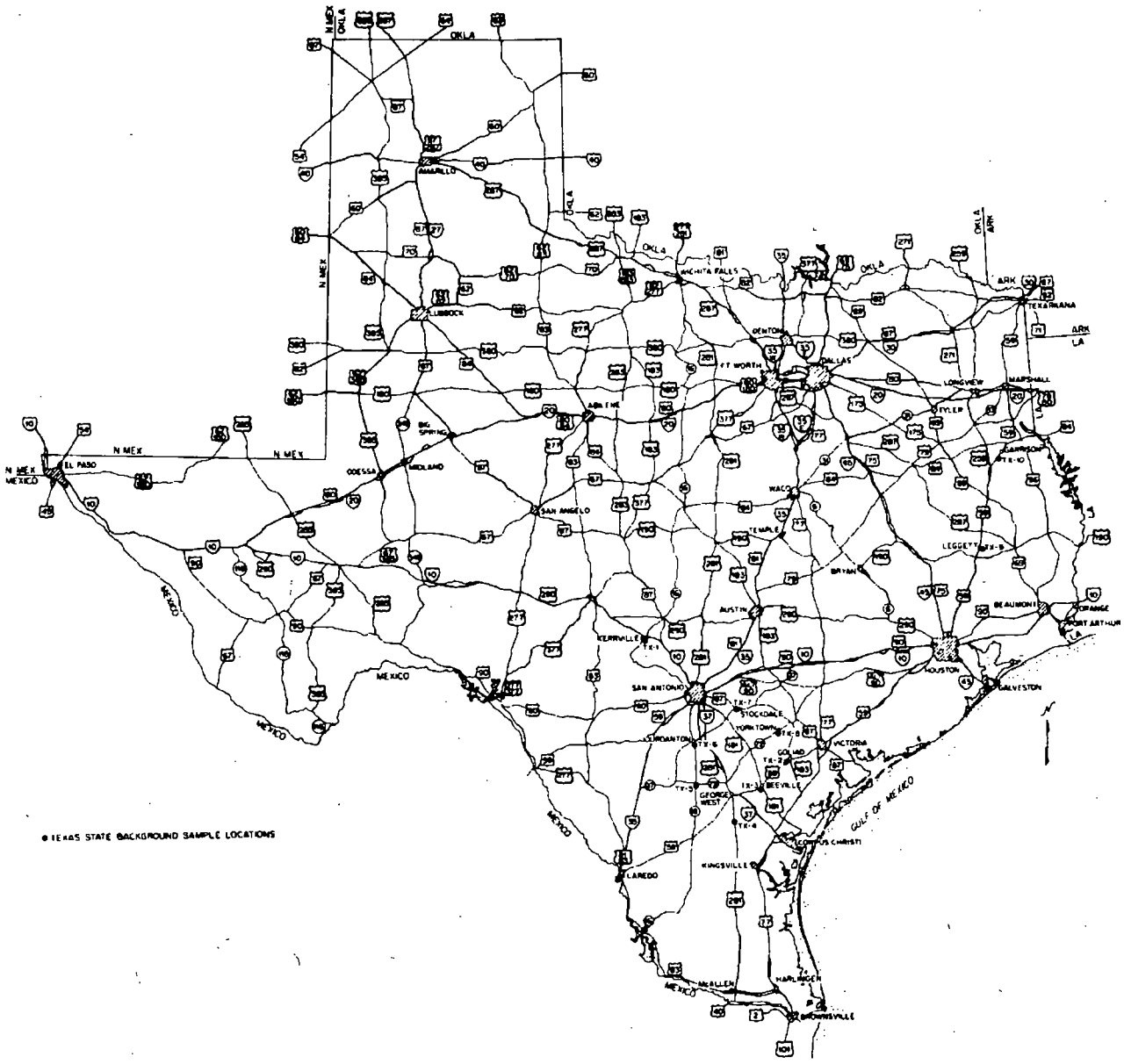

Fig. 29. Location of background samples and external gamma-ray exposure rate measurements in Texas.

Table 30. Background radiation levels and nuclide concentrations in surface soil samples in the State of Utah

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
UT-1	NW corner of intersection of Hwys 68 and Alt. 50, downtown Salt Lake City, Utah	7.1	1.9 ± 0.12	0.75 ± 0.06	1.6
UT-2	NE corner of intersection of Hwy Alt. 50 and 5600 S. St., in W Salt Lake City, Utah	7.9	1.5 ± 0.12	1.1 ± 0.18	0.96
UT-3	N side of Hwy 40, just S of the Great Salt Lake, W of Salt Lake City, Utah	6.4	1.0 ± 0.14	0.20 ± 0.02	1.9
UT-4	Approx. 2 km N of Hwy 40, along the Surplus Canal, about 3 km W of the Salt Lake City International Airport No. 1	11	1.5 ± 0.12	1.1 ± 0.12	1.0
UT-5	Intersection of Hwy 68 and 500 S St., W side of Hwy 68 in North Salt Lake City, Utah	9.0	1.1 ± 0.12	0.78 ± 0.12	0.92
UT-6	NE corner of intersection of Burke La. and Grover La. in Farmington, Utah	11	1.8 ± 0.18	1.7 ± 0.22	1.2
UT-7	S side of Hwy 127, just W of intersection with Hwy 110, W side of Syracuse, Utah	7.0	1.9 ± 0.08	2.3 ± 0.14	1.5
UT-8	Approx. 2 km E of Hwy 89, in Wasatch National Forest, E of South Weber, Utah	11	1.2 ± 0.08	1.7 ± 0.14	2.4
UT-9	N side of Emigration Canyon Rd., E of Hwy 40 in SE Salt Lake City, Utah	6.5	1.0 ± 0.08	0.88 ± 0.06	0.72
UT-10	E side of Hwy 68, E of intersection with Hwy 173 in Murray, Utah	7.3	1.7 ± 0.20	1.3 ± 0.10	1.1
UT-11	Intersection of Hwys 173 and 111, S of Baccaus, Utah, in NE corner	8.8	1.5 ± 0.14	1.1 ± 0.06	0.94
UT-12	NE corner of intersection of Hwys 111 and 48, ~6 km SW of Salt Lake City International Airport No. 2	10	1.5 ± 0.12	1.5 ± 0.06	1.0
UT-13	E side of Hwy 71, between 10600 and 12400 S St. in Sandy, Utah	9.5	1.2 ± 0.12	1.4 ± 0.08	1.8
UT-14	SE corner of intersection of Hwys 152 and 210, along S bank of Big Cottonwood Creek, E of Bulerville, Utah	10	1.7 ± 0.14	1.5 ± 0.14	1.3
UT-15	SW corner of intersection of Hwys 73 and 68, W of Lehi, Utah	9.5	1.6 ± 0.14	1.5 ± 0.18	0.93
UT-16	E side of Hwy 146 at junction with Hwy 80 SE of Alpine, Utah	7.9	1.7 ± 0.14	1.2 ± 0.08	1.0
UT-17	N side of access to Provo Boat Harbor, ~5 km W of Hwy 114, N of Provo Municipal Airport	6.0	1.4 ± 0.12	0.83 ± 0.04	0.83

Table 30. (continued)

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
UT-18	N side of Hwy 80 at Utah-Wasatch County line, near Wildwood, Utah	5.9	1.5 ± 0.10	0.76 ± 0.06	0.94
UT-19	NE corner of intersection of Hwy 163 and road to Monument Valley mill site, ~1.3 km S of Mexican Hat, Utah	8.9	0.75 ± 0.02	[c]	0.57
UT-20	Approx. 4.8 km S of Blanding, Utah, E side of Hwy 163 at airport entrance	10	1.1	[c]	0.94
UT-21	Intersection of Hwys 163 and 6-50, SE side of Cresent Junction, Utah	7.9	0.83 ± 0.08	0.63 ± 0.06	0.78
UT-22	E side of Hwy 50, at White River, N of Colton, Utah	9.9	1.0 ± 0.06	0.71 ± 0.08	1.2
UT-23	N side of Hwy 40, at intersection with Hwy 45, in NE Utah, ~16 km W of Utah-Colorado border	9.0	1.0 ± 0.16	0.90 ± 0.14	0.92
UT-24	Approx. 1.2 km N of I-70 on W side of Hwy 6-50, ~8 km W of Green River, Utah	12	1.4 ± 0.08	1.1 ± 0.08	1.6
UT-25	Approx. 19 km W of Green River, Utah, at intersection of I-70 and Hwy 24	5.0	1.0 ± 0.10	[c]	0.71
UT-26	Approx. 21 km S of I-70, on Hwy 24 toward Hanksville, Utah	6.6	0.54 ± 0.04	0.26 ± 0.02	0.46
UT-27	Approx. 16 km E of Hwy 24 at end of Twist Gap Rd.	5.2	0.53 ± 0.06	0.59 ± 0.08	0.55
UT-28	N of I-70 ~19 km, on dirt road along Green River, N of Green River, Utah	7.2	0.79 ± 0.08	0.79 ± 0.08	0.77
UT-29	Entrance to Devils Garden in Arches National Park, N of Moab, Utah	9.2	0.93 ± 0.10	[c]	1.3
UT-30	N side of I-80 ~22 km E of Knolls, Utah	14	1.2 ± 0.12	0.96 ± 0.08	0.96
UT-31	Approx. 16 km E of Wendover, Utah, N side of I-80 in the Bonneville Salt Flats	7.7	1.4 ± 0.06	1.2 ± 0.08	1.3
UT-32	NW corner of intersection of I-80 and I-15, at Tremonton, Utah	14	1.5 ± 0.08	1.7 ± 0.10	1.0

[a] Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b] Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

[c] No data obtained.

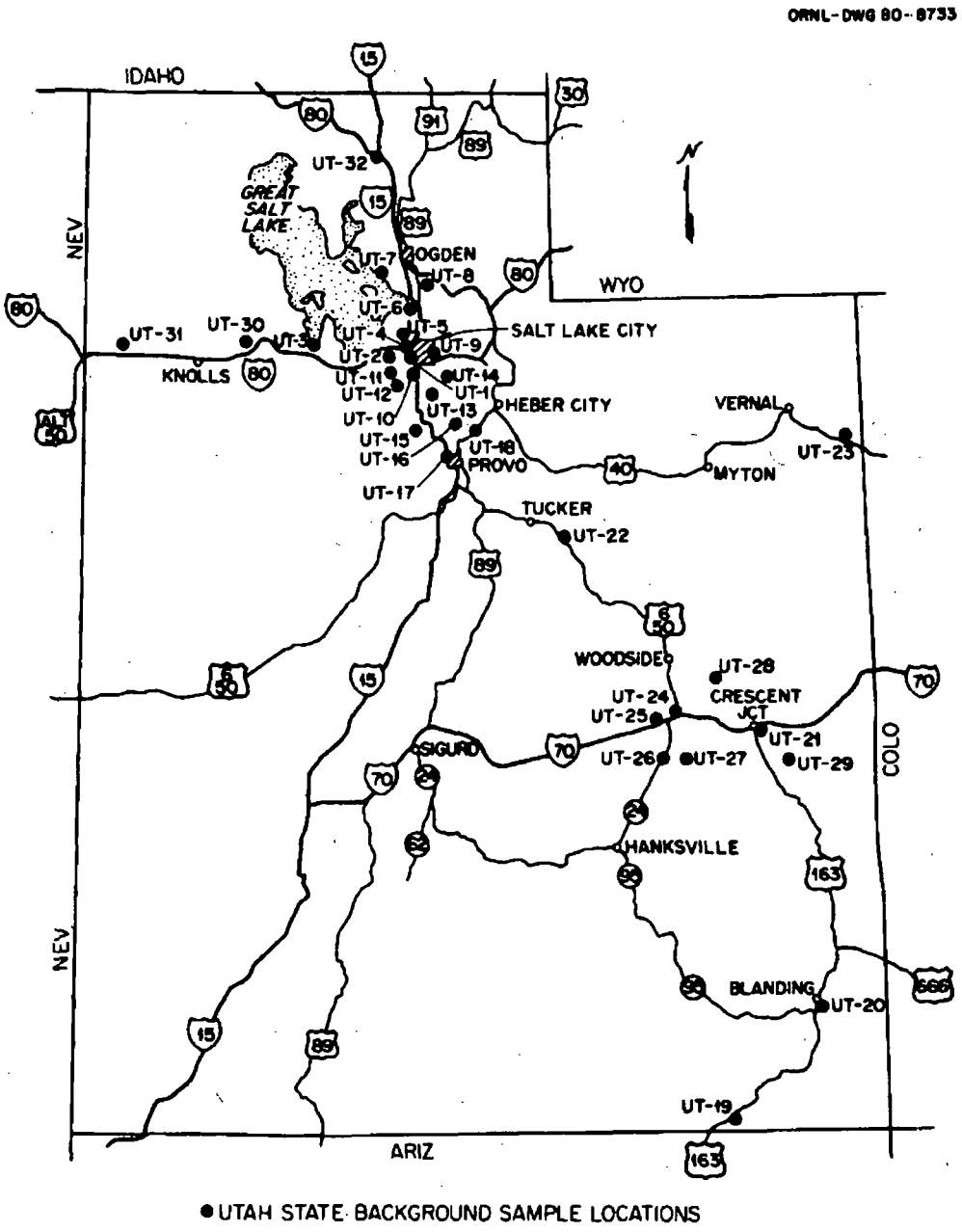

Fig. 30. Location of background samples and external gamma-ray exposure rate measurements in Utah.

Table 31. Background radiation levels and nuclide concentrations in surface soil samples in the State of Virginia

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
VA-1	E side of I-81 in rest area ~24 km N of Bristol, Virginia	4.5	1.1 ± 0.04	0.98 ± 0.04	0.89
VA-2	E side of I-81, ~2.4 km N of Hwy 680 intersection, W of Wytheville, Virginia.	7.9	1.1 ± 0.10	0.85 ± 0.04	0.97
VA-3	E side of I-81, 0.8 km S of Hwy 232-605 at Newbern, Virginia	11	0.62 ± 0.04	0.93 ± 0.08	0.78
VA-4	Approx. 1.6 km N of intersection of I-81 and Hwy 115, on E side of I-81, N of Roanoke, Virginia	6.3	0.66 ± 0.04	1.0 ± 0.06	1.1
VA-5	E side of I-81, ~0.8 km S of intersection with Hwy 60, near Buena Vista, Virginia	11	0.92 ± 0.04	0.79 ± 0.06	0.93
VA-6	E side of I-81, ~0.8 km S of intersection with Hwy 256, near Sidney, Virginia	5.3	1.1 ± 0.06	0.91 ± 0.06	1.3
VA-7	S side of Hwy 211, E of I-81 at Visitors Center in National Forest, W of Luray, Virginia	8.2	0.78 ± 0.06	0.94 ± 0.06	1.1
VA-8	Approx. 6.4 km W of Amissville, Virginia, on S side of Hwy 211	13	0.81 ± 0.04	1.4 ± 0.06	1.0
VA-9	S side of Hwy 50, about 1½ blocks W of I-495 loop in Fairfax, Virginia	6.8	0.97 ± 0.06	0.94 ± 0.06	0.86
VA-10	W side of I-95 in NW corner of intersection with Hwy 642, ~3.2 km SW of Woodbridge, Virginia	4.4	0.60 ± 0.06	0.42 ± 0.04	0.68
VA-11	Rest stop on W side of I-95, ~18 km N of Richmond, Virginia	3.9	0.76 ± 0.08	0.63 ± 0.08	0.85
VA-12	NW corner of intersection of I-85 and Hwy 40, near McKenney, Virginia	4.8	0.62 ± 0.04	0.55 ± 0.04	0.78
VA-13	SW corner of intersection of I-81 and Hwy 55, near Strasburg, Virginia	9.1	1.0 ± 0.10	0.84 ± 0.10	1.1

[a] Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b] Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

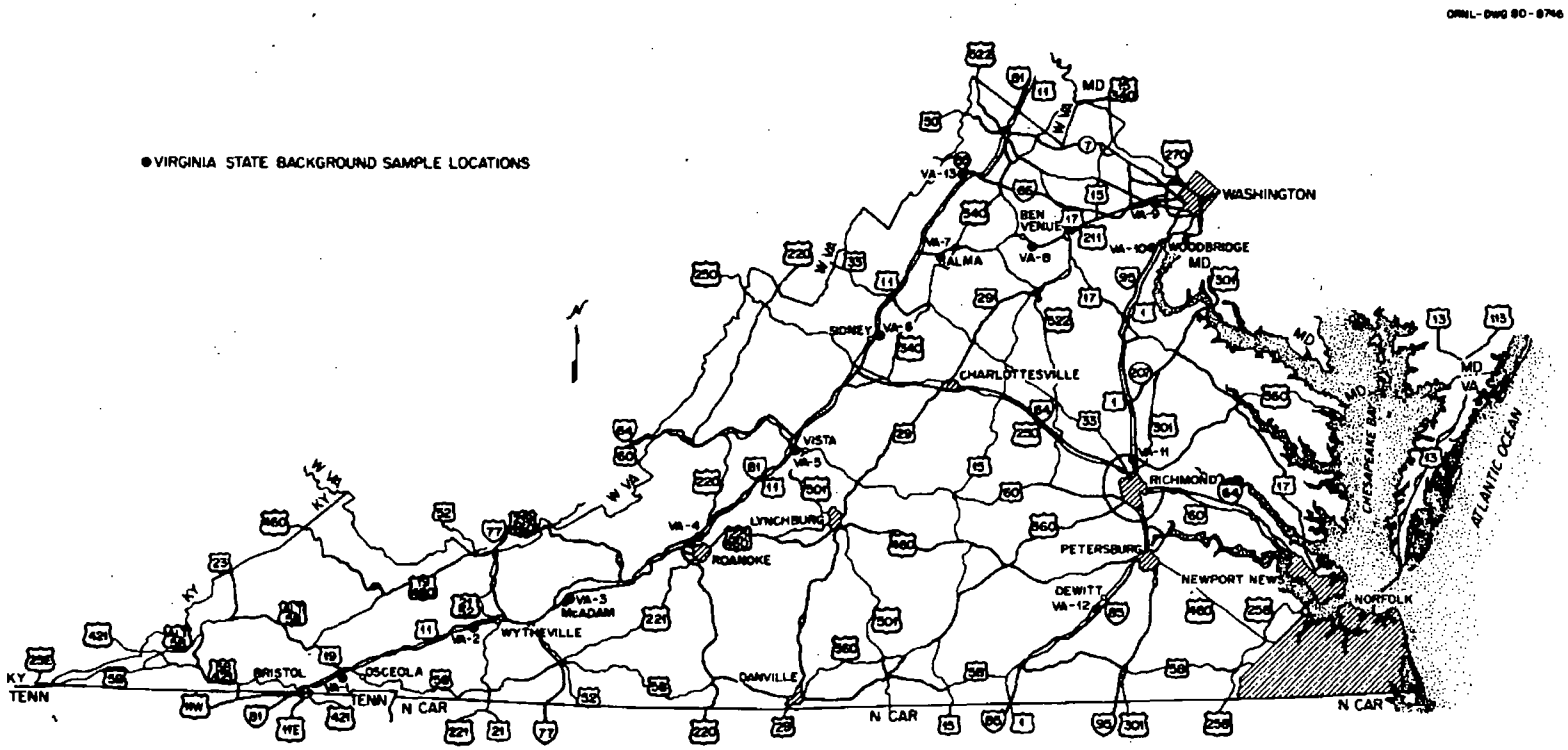

Fig. 31. Location of background samples and external gamma-ray exposure rate measurements in Virginia.

Table 32. Background radiation levels and nuclide concentrations in surface soil samples in the State of West Virginia

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
WV-1	Along Hwy 219 at Parsons, West Virginia	6.0	1.2 ± 0.06	1.6 ± 0.06	1.3
WV-2	Along Hwy 50 at Macomber, West Virginia	7.0	0.84 ± 0.08	1.1 ± 0.08	1.2
WV-3	Along Hwy 30 at West Virginia-Pennsylvania border, near Chester, West Virginia	8.2	1.5 ± 0.10	1.4 ± 0.18	1.5
WV-4	Along I-79 at Lost Creek, West Virginia	10	1.5 ± 0.10	1.6 ± 0.14	1.5
WV-5	NW corner of intersection of I-79 and Hwy 119, near Wellford, West Virginia	6.0	0.78 ± 0.06	1.4 ± 0.06	1.5
WV-6	W side of I-79, ~1.6 km S of intersection with Hwy 19, just N of Canfield, West Virginia	8.2	1.3 ± 0.08	1.3 ± 0.10	1.2
WV-7	NE corner of intersection of I-64 and Hwy 34, ~10 km S of Winfield, West Virginia	4.6	0.88 ± 0.08	1.1 ± 0.08	1.3
WV-8	W side of I-81, ~8 km N of West Virginia-Virginia border, near Bunker Hill, West Virginia	9.4	1.3 ± 0.06	1.2 ± 0.06	1.1
WV-9	SE corner of intersection of I-77 and Hwy 27, ~5 km N of Charleston, West Virginia	11	1.5 ± 0.04	1.5 ± 0.16	1.8
WV-10	NW corner of intersection of I-77 and Hwy 33, at Ripley, West Virginia	5.9	1.6 ± 0.08	1.4 ± 0.12	1.8
WV-11	E side of I-77, ~2.4 km S of intersection with Hwy 50, at Parkersburg, West Virginia	8.0	1.3 ± 0.04	1.2 ± 0.08	1.6

[a] Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b] Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are ≤5% (2σ).

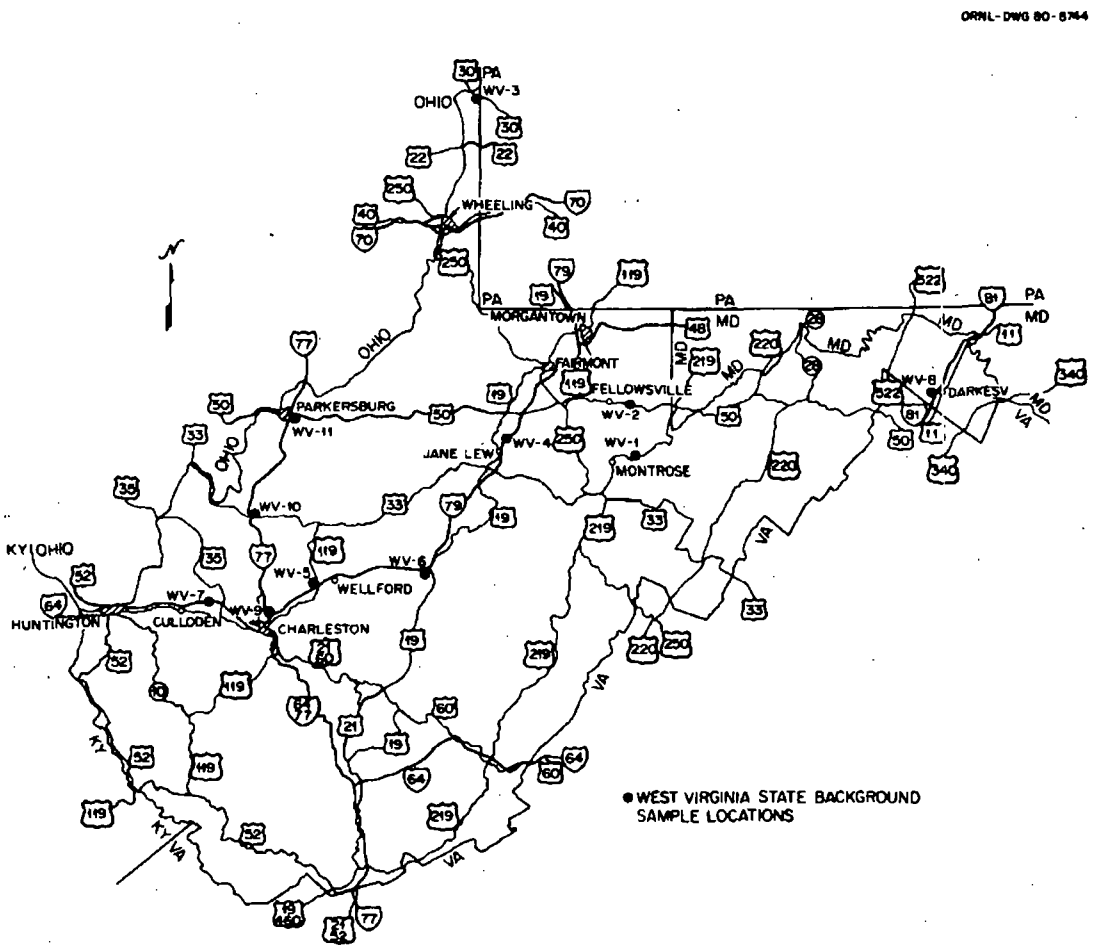

Fig. 32. Location of background samples and external gamma-ray exposure rate measurements in West Virginia.

Table 33. Background radiation levels and nuclide concentrations in surface soil samples in the State of Wyoming

Sample designation	Description of sample location	Average external gamma exposure rate (μR/h)[a]	Nuclide concentration in surface soil (pCi/g)[b]		
			^{226}Ra	^{232}Th	^{238}U
WY-1	E side of Hwy 789, ~1.6 km N of Wyoming-Colorado border, at Baggs, Wyoming	14	0.91 ± 0.04	1.1 ± 0.10	0.93
WY-2	Approx. 1.6 km NW of intersection of Hwys 220 and 287, NW of Muddy Gap, Wyoming	20	1.3 ± 1.2	1.5 ± 1.3	0.98
WY-3	S side of Hwy 789, ~3.2 km NE of Lander, Wyoming	13	1.1 ± 0.08	0.93 ± 0.10	0.87
WY-4	Just W of intersection of Hwys 26 and 287, S side of road, W of Morton, Wyoming	12	0.80 ± 0.06	1.8 ± 0.12	0.82
WY-5	Junction of Hwys 26 and 89, near Moran, Wyoming, at entrance to Grand Teton Park	11	1.4 ± 0.22	0.87 ± 0.10	0.98
WY-6	Approx. 1.6 km S of intersection of Hwys 16 and 120, S of Cody, Wyoming	10	1.3 ± 0.14	1.2 ± 0.16	1.2
WY-7	Approx. 1.6 km E of Shoshoni, Wyoming on S side of Hwy 26	13	0.92 ± 0.08	1.1 ± 0.06	0.93
WY-8	Port of Entry in Casper, Wyoming on I-25	15	0.65 ± 0.04	0.70 ± 0.10	0.66
WY-9	SW corner of intersection of Hwys 487 and 91, N of Medicine Bow, Wyoming	15	0.73 ± 0.08	0.59 ± 0.12	0.79
WY-10	Approx. 0.8 km S of I-80, on W side of Hwy 789, about 21 km E of Wamsutter, Wyoming	16	0.95 ± 0.10	0.69 ± 0.06	0.83
WY-11	Approx. 16 km N of Douglas, Wyoming, on S side of North Platte River, at Hwy 93 bridge	12	1.7 ± 0.22	[c]	1.9
WY-12	W of rest area at intersection of I-25 and Hwy 314, near Slater, Wyoming	11	0.97 ± 0.04	1.2 ± 0.10	1.3
WY-13	At Wyoming-Colorado border, on W side of I-25, S of Cheyenne, Wyoming	15	0.82 ± 0.04	1.1 ± 0.06	0.89

[a] Exposure rate determined from 3 to 4 measurements at each location using a "Phil" tube as described in Appendix I.

[b] Standard deviation of ^{226}Ra and ^{232}Th measurements are given as the 2σ value. Error in the ^{238}U measurements are $\leq 5\%$ (2σ).

[c] No data obtained.

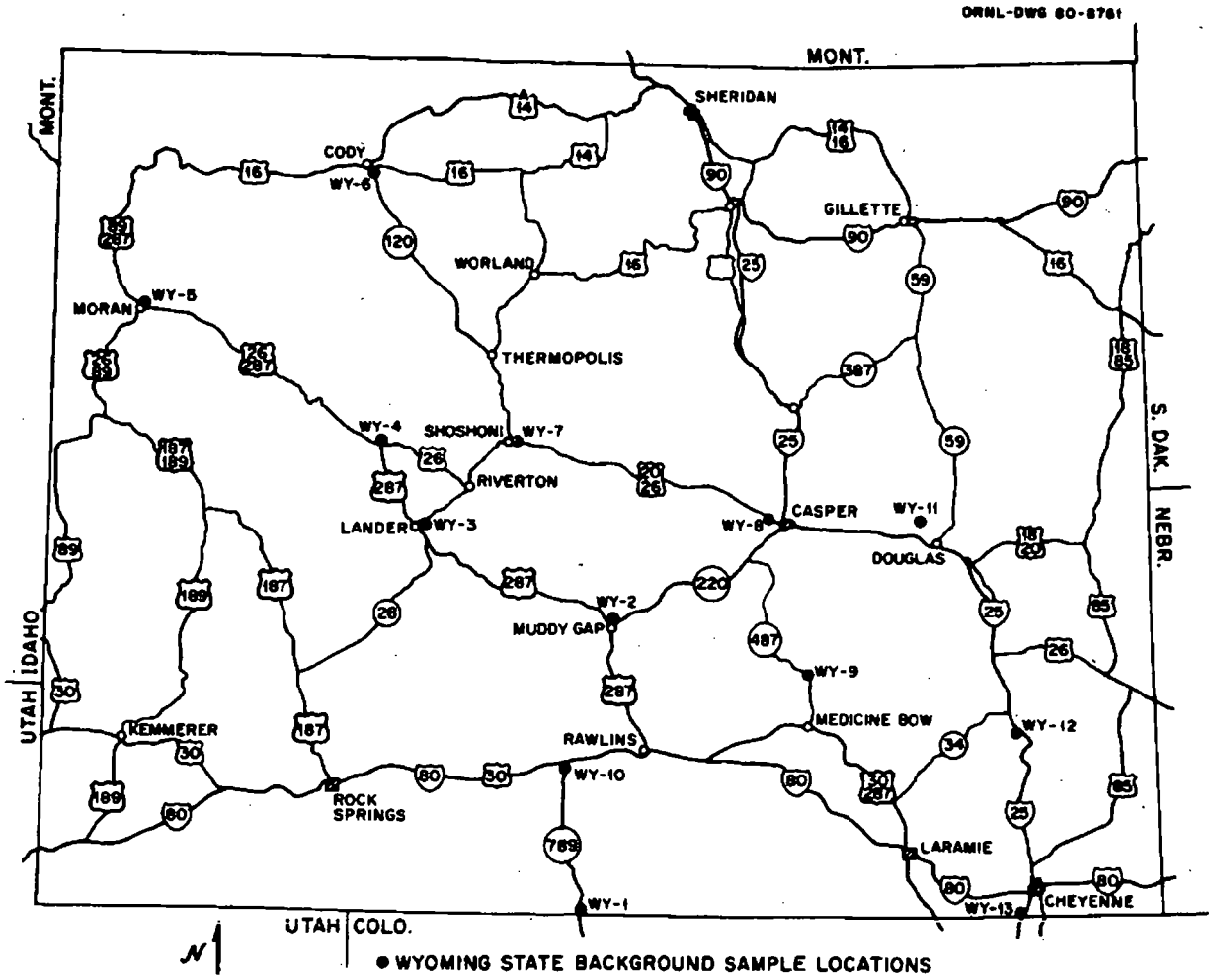

Fig. 33. Location of background samples and external gamma-ray exposure rate measurements in Wyoming.

Table 34. Summary of state background external gamma exposure rate measurements[a]

State	Number of measurements taken	Range of values (μR/h)	Arithmetic mean and standard deviation[b] (μR/h)	Geometric mean and standard deviation[c] (μR/h)
Alabama	8	3.0 - 7.8	4.8 ± 3.5	4.5 : 1.4
Alaska	*d*	*d*	*d*	*d*
Arizona	6	5.3 - 12	9.3 ± 5.4	8.9 : 1.4
Arkansas	1	11	11[e]	11[e]
California	3	9.0 - 11	10 ± 2.3	10 : 1.1
Colorado	32	6.3 - 34	14 ± 10	14 : 1.4
Delaware	2	5.0 - 6.9	6.0 ± 2.6	5.9 : 1.3
Florida	11	<1.0 - 7.4	4.0 ± 3.2	3.6 : 1.7
Georgia	9	1.9 - 9.0	5.1 ± 4.2	4.7 : 1.6
Idaho	13	11 - 16	12 ± 3.2	12 : 1.1
Illinois	8	7.2 - 11	8.1 ± 2.5	8.0 : 1.2
Indiana	2	6.0 - 7.1	6.6 ± 1.5	6.5 : 1.1
Kansas	6	6.6 - 14	10 ± 5.2	9.8 : 1.3
Kentucky	12	3.9 - 11	7.4 ± 4.6	7.0 : 1.4
Louisiana	3	3.5 - 6.0	5.1 ± 2.7	4.9 : 1.4
Maryland	5	4.5 - 8.8	6.6 ± 3.2	6.4 : 1.3
Michigan	*d*	*d*	*d*	*d*
Mississippi	3	4.3 - 11	8.0 ± 6.7	7.4 : 1.6
Missouri	10	4.6 - 10	6.8 ± 3.2	6.6 : 1.3
Nevada	6	11 - 19	14 ± 5.7	14 : 1.2
New Jersey	23	2.3 - 13	6.1 ± 4.8	5.7 : 1.5
New Mexico	13	6.8 - 16	10 ± 5.4	9.7 : 1.3
New York	*d*	*d*	*d*	*d*
North Carolina	8	3.2 - 13	8.2 ± 6.5	7.6 : 1.6
Ohio	11	2.8 - 11	6.9 ± 5.0	6.4 : 1.5
Oregon	9	8.2 - 19	11 ± 6.6	11 : 1.3
Pennsylvania	32	2.5 - 14	6.7 ± 5.0	6.2 : 1.5
Tennessee	12	2.9 - 11	6.4 ± 4.8	5.9 : 1.5
Texas	10	1.4 - 5.6	3.3 ± 3.0	3.0 : 1.6
Utah	32	5.0 - 14	8.7 ± 4.5	8.4 : 1.3
Virginia	13	3.9 - 13	7.4 ± 5.8	6.9 : 1.5
West Virginia	11	4.6 - 11	7.7 ± 3.9	7.4 : 1.3
Wyoming	13	10 - 20	14 ± 5.2	13 : 1.2
U. S. Average	327	<1.0 - 34	8.5 ± 4.1	7.5 : 1.7

[a] Summary of data contained in Tables 1-33 for individual states.

[b] Standard deviation of arithmetic mean is the 2σ value.

[c] The geometric standard deviation is a multiplicative parameter to the geometric mean containing 68% (1σ) of the frequency values.

[d] No data on external gamma exposure rates available for the state.

[e] Values for standard deviation cannot be computed.

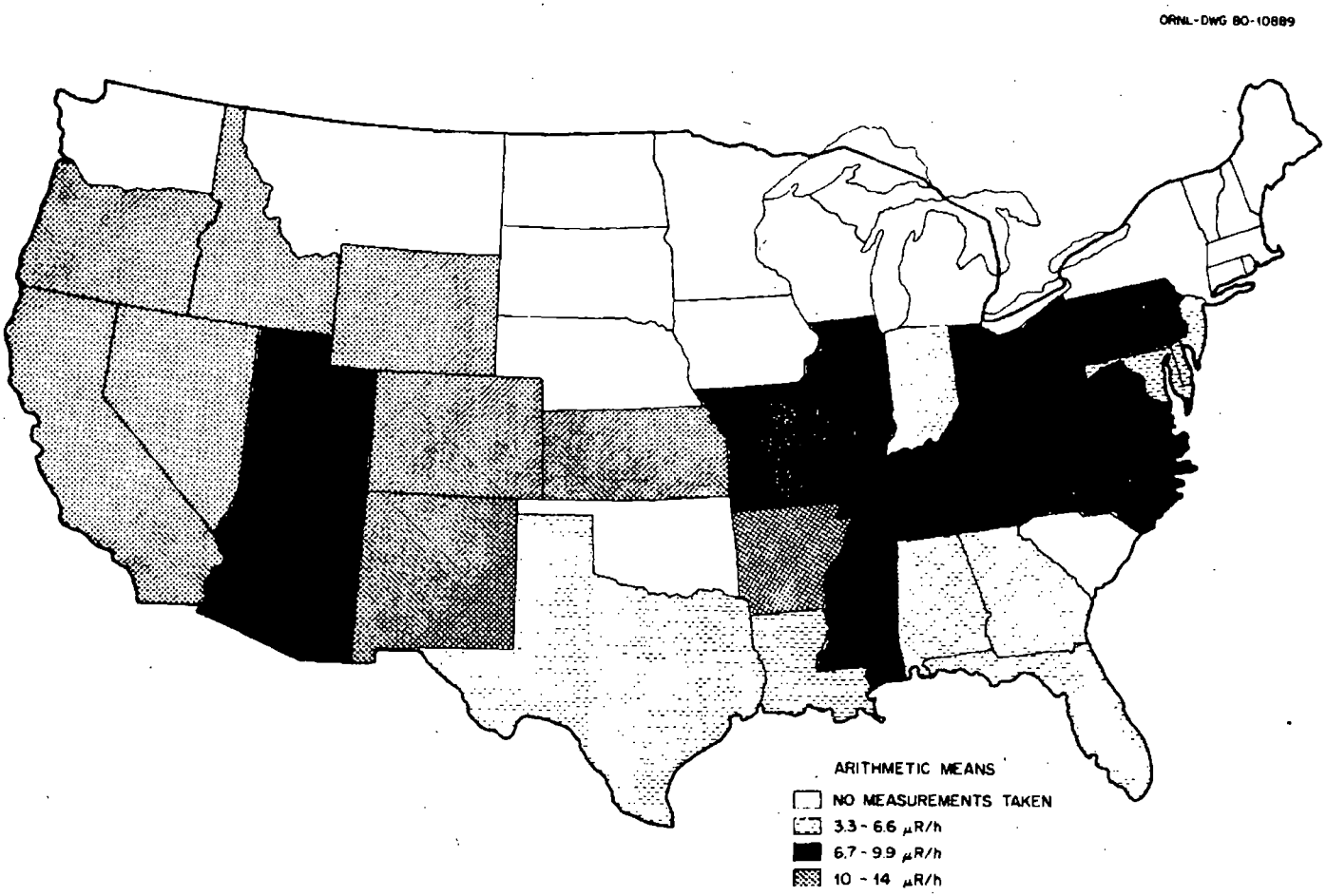

Fig. 34. External gamma-ray exposure rates at 1 m above the ground — State averages.

Table 35. Summary of state background concentrations of ^{226}Ra in surface soil[a]

State	Number of samples analyzed	Range of values (pCi/g)	Arithmetic mean and standard deviation[b] (pCi/g)	Geometric mean and standard deviation[c] (pCi/g)
Alabama	8	0.47 - 1.4	0.82 ± 0.62	0.77 : 1.5
Alaska	6	0.43 - 0.92	0.65 ± 0.32	0.64 : 1.3
Arizona	6	0.23 - 2.0	0.95 ± 1.5	0.70 : 2.4
Arkansas	*d*	*d*	*d*	*d*
California	3	0.24 - 1.3	0.77 ± 1.0	0.62 : 2.4
Colorado	32	0.48 - 3.4	1.4 ± 1.1	1.3 : 1.5
Delaware	2	1.1 - 1.2	1.2 ± 0.14	1.2 : 1.1
Florida	11	0.25 - 2.3	0.84 ± 1.2	0.67 : 2.0
Georgia	9	0.46 - 1.6	0.88 ± 0.77	0.81 : 1.6
Idaho	12	0.64 - 1.6	1.1 ± 0.51	1.1 : 1.3
Illinois	7	0.65 - 1.2	0.97 ± 0.41	0.95 : 1.3
Indiana	2	1.0 - 1.1	1.1 ± 0.07	1.1 : 1.1
Kansas	6	0.34 - 1.4	0.97 ± 0.85	0.86 : 1.8
Kentucky	13	0.81 - 4.2	1.5 ± 1.7	1.4 : 1.5
Louisiana	2	0.58 - 0.84	0.71 ± 0.36	0.70 : 1.3
Maryland	6	0.49 - 1.2	0.72 ± 0.50	0.69 : 1.4
Michigan	10	0.46 - 2.0	1.1 ± 0.97	0.95 : 1.6
Mississippi	3	0.77 - 1.6	1.2 ± 0.82	1.2 : 1.5
Missouri	10	0.31 - 1.4	1.1 ± 0.61	1.0 : 1.6
Nevada	6	0.89 - 2.0	1.5 ± 0.72	1.5 : 1.3
New Jersey	24	0.24 - 1.4	0.87 ± 0.67	0.78 : 1.7
New Mexico	13	0.72 - 2.7	1.5 ± 1.1	1.5 : 1.4
New York	6	0.48 - 1.2	0.85 ± 0.51	0.81 : 1.4
North Carolina	8	0.48 - 1.2	0.78 ± 0.48	0.74 : 1.4
Ohio	12	0.81 - 2.5	1.5 ± 0.93	1.4 : 1.4
Oregon	8	0.24 - 2.1	0.82 ± 1.1	0.68 : 1.9
Pennsylvania	33	0.46 - 2.4	1.2 ± 0.75	1.1 : 1.4
Tennessee	10	0.65 - 1.4	1.1 ± 0.51	1.0 : 1.3
Texas	10	0.54 - 1.4	0.89 ± 0.54	0.85 : 1.4
Utah	32	0.53 - 1.9	1.3 ± 0.74	1.2 : 1.4
Virginia	13	0.60 - 1.1	0.85 ± 0.38	0.83 : 1.3
West Virginia	11	0.78 - 1.6	1.3 ± 0.57	1.2 : 1.3
Wyoming	13	0.65 - 1.7	1.0 ± 0.59	1.0 : 1.3
U. S. Average	327	0.23 - 4.2	1.1 ± 0.48	1.0 : 1.6

[a] Summary of data contained in Tables 1-33 for individual states.

[b] Standard deviation of arithmetic mean is the 2σ value.

[c] The geometric standard deviation is a multiplicative parameter to the geometric mean containing 68% (1σ) of the frequency values.

[d] No data on ^{226}Ra concentration available for state.

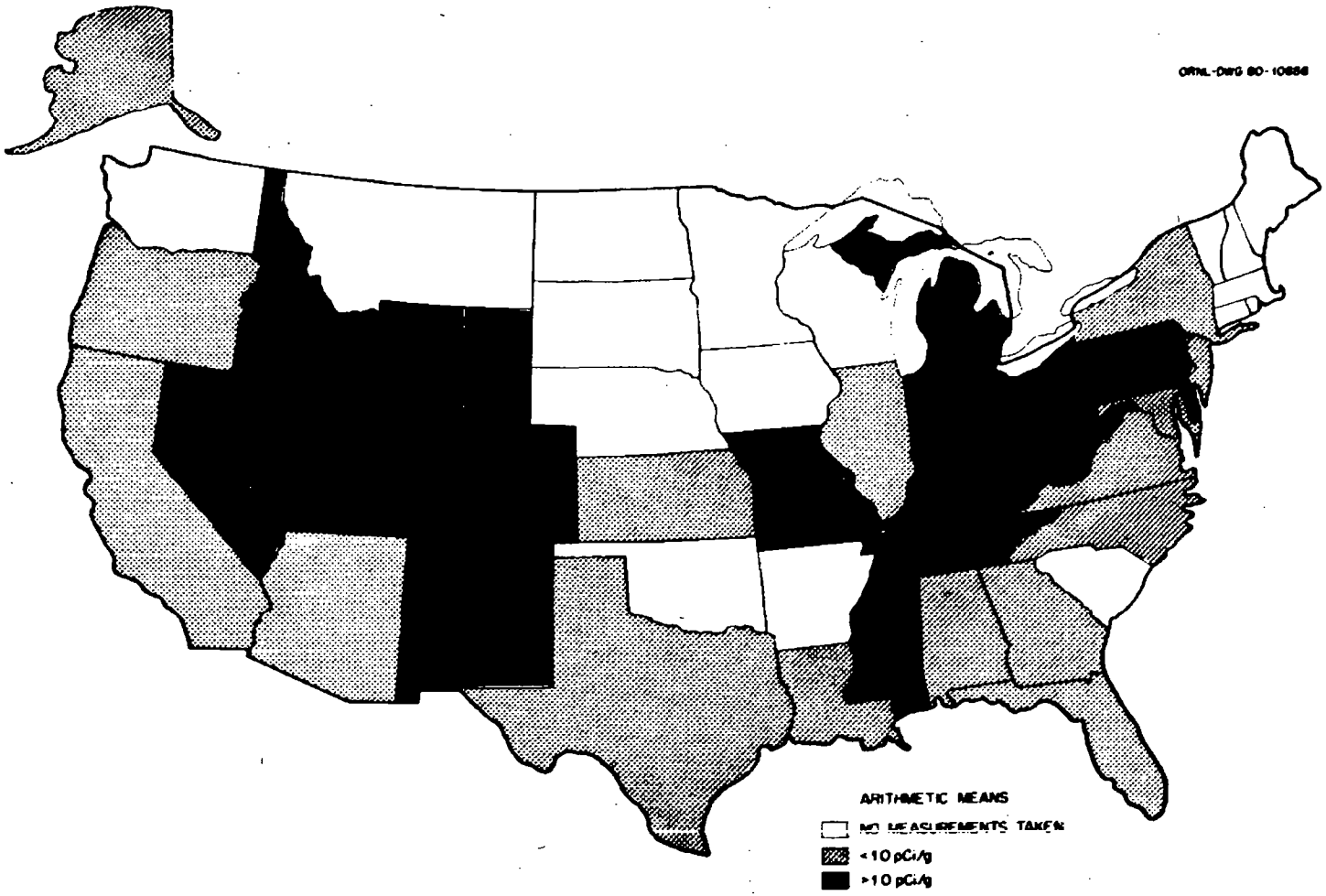

Fig. 35. Concentration of ^{226}Ra in surface soil samples - State averages.

Table 36. Summary of state background concentrations of ^{232}Th in surface soil[a]

State	Number of samples analyzed	Range of values (pCi/g)	Arithmetic mean and standard deviation[b] (pCi/g)	Geometric mean and standard deviation[c] (pCi/g)
Alabama	8	0.36 - 1.5	0.77 ± 0.71	0.70 : 1.6
Alaska	7	0.19 - 2.3	0.87 ± 1.4	0.67 : 2.2
Arizona	6	0.20 - 1.3	0.63 ± 0.83	0.52 : 2.0
Arkansas	1	1.6	1.6[d]	1.6[d]
California	3	0.30 - 0.76	0.54 ± 0.45	0.50 : 1.6
Colorado	20	0.10 - 3.1	1.3 ± 1.4	1.1 : 2.1
Delaware	2	1.2	1.2 ± 0.04	1.2[d]
Florida	10	0.12 - 0.37	0.24 ± 0.13	0.23 : 1.3
Georgia	9	0.28 - 3.4	1.1 ± 1.9	0.85 : 2.1
Idaho	13	0.42 - 1.9	1.2 ± 0.73	1.1 : 1.5
Illinois	8	0.49 - 1.2	0.96 ± 0.43	0.93 : 1.3
Indiana	2	1.1 - 1.2	1.2 ± 0.14	1.2 : 1.1
Kansas	4	0.32 - 1.6	1.3 ± 1.2	1.1 : 2.2
Kentucky	12	0.88 - 1.5	1.2 ± 0.39	1.2 : 1.2
Louisiana	2	0.60 - 0.72	0.66 ± 0.17	0.66 : 1.1
Maryland	6	0.48 - 0.86	0.70 ± 0.28	0.69 : 1.2
Michigan	10	0.24 - 0.82	0.56 ± 0.35	0.53 : 1.5
Mississippi	3	0.81 - 1.7	1.1 ± 0.50	1.1 : 1.5
Missouri	10	0.32 - 1.3	1.0 ± 0.56	0.95 : 1.5
Nevada	6	0.62 - 3.0	1.5 ± 1.6	1.4 : 1.7
New Jersey	23	0.31 - 1.5	0.90 ± 0.66	0.82 : 1.6
New Mexico	13	0.48 - 1.8	0.95 ± 0.73	0.89 : 1.5
New York	6	0.40 - 1.1	0.71 ± 0.52	0.67 : 1.5
North Carolina	8	0.42 - 1.5	0.92 ± 0.83	0.83 : 1.6
Ohio	12	0.71 - 1.5	1.0 ± 0.50	1.0 : 1.3
Oregon	9	0.43 - 1.5	0.72 ± 0.66	0.66 : 1.5
Pennsylvania	33	0.38 - 1.7	1.1 ± 0.53	1.1 : 1.3
Tennessee	11	0.66 - 1.5	0.95 ± 0.50	0.92 : 1.3
Texas	10	0.40 - 1.1	0.73 ± 0.40	0.70 : 1.4
Utah	28	0.20 - 2.3	1.1 ± 0.92	0.97 : 1.7
Virginia	13	0.42 - 1.4	0.86 ± 0.47	0.83 : 1.4
West Virginia	11	1.1 - 1.6	1.4 ± 0.35	1.3 : 1.2
Wyoming	12	0.59 - 1.8	1.1 ± 0.68	1.0 : 1.4
U. S. Average	331	0.10 - 3.4	0.98 ± 0.46	0.87 : 1.7

[a] Summary of data contained in Tables 1-33 for individual states.

[b] Standard deviation of arithmetic mean is the 2σ value.

[c] The geometric standard deviation is a multiplicative parameter to the geometric mean containing 68% (1σ) of the frequency values.

[d] Values for standard deviation cannot be computed.

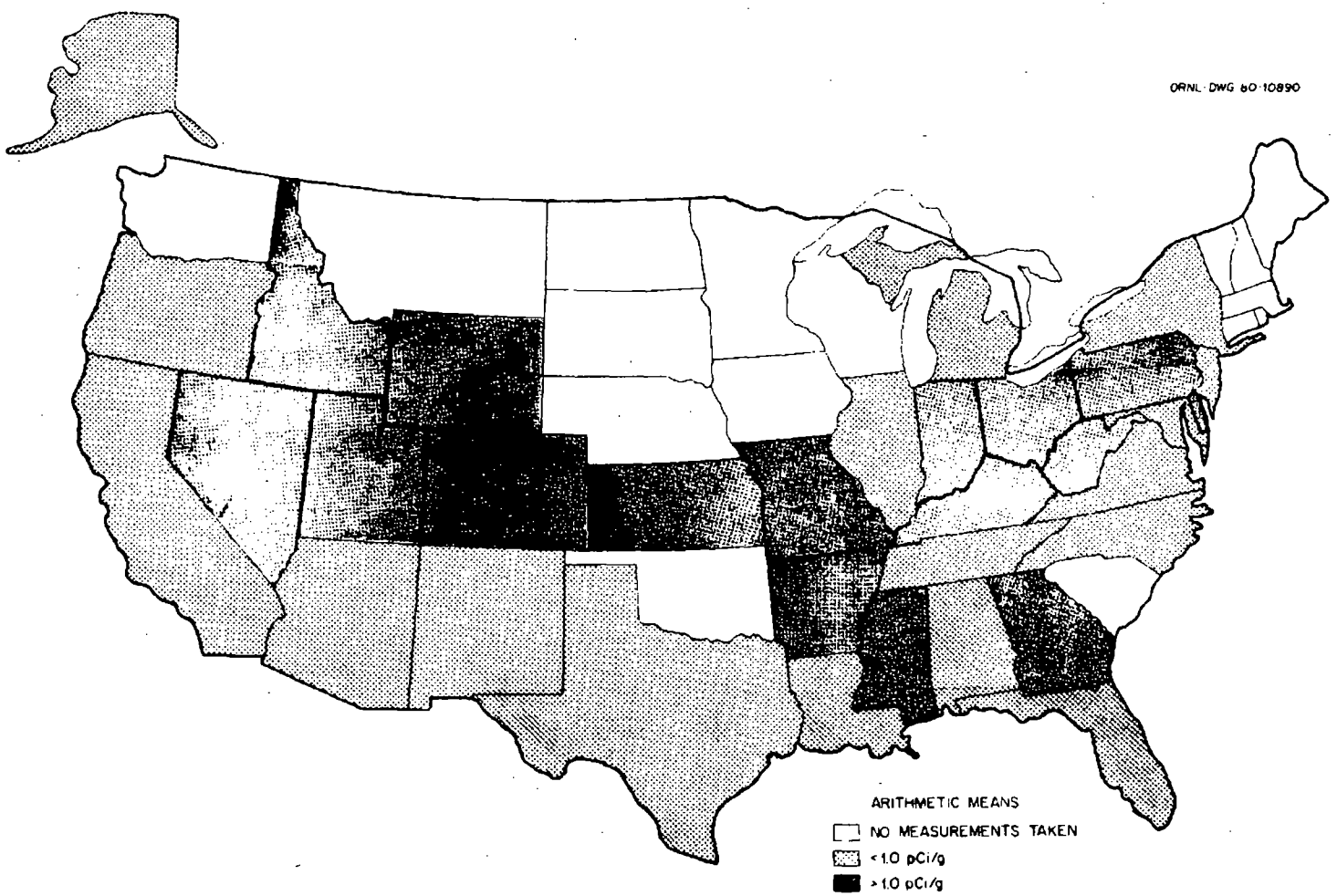

Fig. 36. Concentration of ^{232}Th in surface soil samples - State averages.

Table 37. Summary of state background concentrations of ^{238}U in surface soil[a]

State	Number of samples analyzed	Range of values (pCi/g)	Arithmetic mean and standard deviation[b] (pCi/g)	Geometric mean and standard deviation[c] (pCi/g)
Alabama	8	0.51 - 1.1	0.85 ± 0.36	0.83 : 1.3
Alaska	7	0.39 - 0.80	0.63 ± 0.30	0.61 : 1.3
Arizona	6	0.27 - 1.83	0.82 ± 1.1	0.67 : 2.0
Arkansas	1	1.5	1.5	1.5[d]
California	3	0.19 - 1.3	0.78 ± 1.1	0.59 : 2.7
Colorado	32	0.47 - 3.0	1.2 ± 0.91	1.2 : 1.4
Delaware	2	1.1 - 1.2	1.2 ± 0.10	1.2 : 1.0
Florida	11	0.12 - 2.0	0.71 ± 1.3	0.47 : 2.7
Georgia	9	0.48 - 1.6	0.85 ± 0.72	0.79 : 1.5
Idaho	13	0.66 - 2.2	1.1 ± 0.88	1.1 : 1.4
Illinois	8	0.64 - 1.4	1.1 ± 0.45	1.0 : 1.3
Indiana	2	1.1 - 1.4	1.3 ± 0.31	1.3 : 1.1
Kansas	6	0.58 - 1.4	1.1 ± 0.60	1.0 : 1.4
Kentucky	13	1.1 - 3.8	1.6 ± 1.4	1.5 : 1.4
Louisiana	3	0.44 - 0.81	0.58 ± 0.40	0.56 : 1.4
Maryland	6	0.54 - 0.93	0.78 ± 0.30	0.77 : 1.2
Michigan	10	0.34 - 1.2	0.73 ± 0.55	0.68 : 1.5
Mississippi	3	0.69 - 1.7	1.1 ± 1.1	0.98 : 1.6
Missouri	10	0.33 - 1.7	1.1 ± 0.73	0.99 : 1.6
Nevada	6	0.74 - 1.8	1.3 ± 0.65	1.3 : 1.3
New Jersey	24	0.13 - 1.4	0.86 ± 0.68	0.76 : 1.8
New Mexico	13	0.53 - 1.5	1.1 ± 0.55	1.0 : 1.3
New York	6	0.76 - 1.2	0.95 ± 0.26	0.94 : 1.2
North Carolina	8	0.39 - 1.6	0.87 ± 0.71	0.81 : 1.5
Ohio	12	0.76 - 2.2	1.4 ± 0.79	1.3 : 1.4
Oregon	9	0.50 - 2.0	0.84 ± 0.89	0.76 : 1.5
Pennsylvania	33	0.41 - 1.9	1.2 ± 0.59	1.1 : 1.4
Tennessee	12	0.72 - 1.3	1.0 ± 0.39	1.0 : 1.2
Texas	10	0.48 - 1.5	0.82 ± 0.59	0.78 : 1.4
Utah	32	0.46 - 2.4	1.1 ± 0.82	1.0 : 1.4
Virginia	13	0.68 - 1.3	0.95 ± 0.34	0.94 : 1.2
West Virginia	11	1.1 - 1.8	1.4 ± 0.53	1.4 : 1.2
Wyoming	13	0.66 - 1.9	1.0 ± 0.63	0.97 : 1.3
U. S. Average	355	0.12 - 3.8	1.0 ± 0.83	0.96 : 1.6

[a] Summary of data contained in Tables 1-33 for individual states.

[b] Standard deviation of arithmetic mean is the 2σ value.

[c] The geometric standard deviation is a multiplicative parameter to the geometric mean containing 68% (1σ) of the frequency values.

[d] Values for geometric standard deviation cannot be computed.

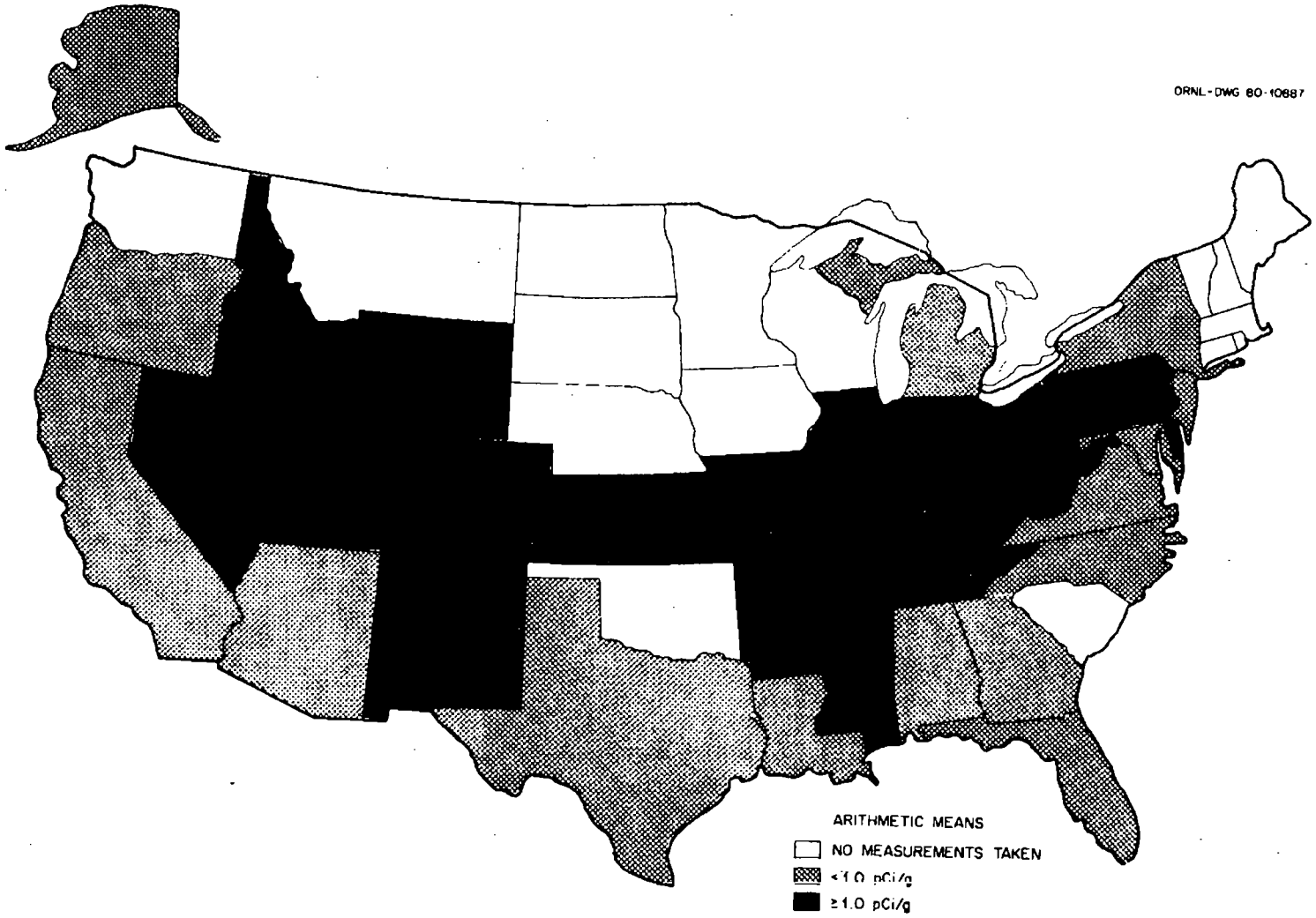

Fig. 37. Concentration of ^{238}U in surface soil samples - State averages.

Table 38. Ground surveys of background radiation in the United States

Reference	Location	Instrumentation	Remarks
Solon, 1960[5]	38 U.S. towns and cities	Ion chamber	125 measurements
Stephens et al., 1961[6]	30 locations near San Francisco	Portable scintillator	
Beck et al., 1964[7]	Approx. 115 locations in 23 states	Spectrometer and ion chamber	2-3 measurements/location, some taken in different years
Segall, and Reed, 1964[8]	New Hampshire, Vermont	Personal dosimeters (ion chambers)	400 people; performed concurrently with Lowder and Condon (1965)
Lowder and Condon, 1965[9]	New Hampshire, Vermont	Spectrometer Portable scintillator	Outdoors Indoors–160 homes and apartments
Wollenberg et al., 1969[10]	30 locations near San Francisco (same as Stephens et al., 1961)	Portable scintillator	
Levin et al., 1968[11]	1,102 towns in 24 states	Portable scintillator	9,026 measurements; all states were east of the Mississippi River except Iowa, Minnesota, and Colorado
Golden, 1968[12]	Florida–vicinity of phosphate beds	Portable scintillator	1,161 measurements, majority in south-western Polk County, Florida
Yeates et al., 1970[13]	Boston, Massachusetts	Ion chamber	6 measurements outdoors 15 measurements/6 frame dwellings 3 measurements/3 apts. 16 measurements/4 office bldgs.
Lindeken et al.,1971[14]	107 locations across the U.S.	Thermoluminescent dosimeters	Outdoors at U.S. weather stations

Table 39. Comparison of state background external gamma exposure rate measurements[a]

State	ORNL[b]		Levin[c]		Lindekin[d]		Beck[e]	
	No. of locations	Mean exposure rate (μR/h)	No. of locations	Mean exposure rate (μR/h)	No. of locations	Mean exposure rate (μR/h)	No. of locations	Mean exposure rate (μR/h)
Alabama	8	4.8 ± 3.5	*f*	*f*	*f*	*f*	4	11 ± 3.8
Alaska	*f*	*f*	*f*	*f*	11	6.3 ± 2.9	*f*	*f*
Arizona	6	9.3 ± 5.4	*f*	*f*	2	12 ± 1.1	*f*	*f*
Arkansas	1	11	*f*	*f*	1	10	1	12
California	3	10 ± 2.3	*f*	*f*	5	12 ± 10	8	7.2 ± 5.9
Colorado	32	14 ± 10	11	13 ± 1.7	2	17 ± 6.2	15	12 ± 4.0
Connecticut	*f*	*f*	56	10 ± 1.9	*f*	*f*	*f*	*f*
Delaware	2	6.0 ± 2.6	10	9.1 ± 1.7	*f*	*f*	*f*	*f*
Florida	11	4.0 ± 3.2	239	6.7 ± 2.0	5	5.8 ± 3.1	*f*	*f*
Georgia	9	5.1 ± 4.2	91	9.2 ± 2.8	3	11 ± 6.7	1	11
Hawaii	*f*	*f*	*f*	*f*	3	4.2 ± 0.92	*f*	*f*
Idaho	13	12 ± 3.2	*f*	*f*	2	13 ± 3.0	*f*	*f*
Illinois	8	8.1 ± 2.5	67	9.0 ± 1.2	2	10 ± 0.14	3	10 ± 0.69
Indiana	2	6.6 ± 1.5	*f*	*f*	1	11	*f*	*f*
Iowa	*f*	*f*	62	8.8 ± 1.1	1	9.1	*f*	*f*
Kansas	6	10 ± 5.2	*f*	*f*	1	11	3	10 ± 1.6
Kentucky	12	7.4 ± 4.6	30	9.5 ± 1.6	1	9.8	*f*	*f*
Louisiana	3	5.1 ± 2.7	*f*	*f*	2	8.1 ± 3.4	1	8.5
Maine	*f*	*f*	87	9.8 ± 1.5	2	10 ± 3.4	*f*	*f*
Maryland	5	6.6 ± 3.2	22	8.4 ± 1.2	*f*	*f*	*f*	*f*
Massachusetts	*f*	*f*	58	9.9 ± 1.7	*f*	*f*	*f*	*f*
Michigan	*f*	*f*	23	7.8 ± 1.3	1	8.6	*f*	*f*
Minnesota	*f*	*f*	18	8.7 ± 0.63	3	9.1 ± 1.9	1	8.7
Mississippi	3	8.0 ± 6.7	*f*	*f*	1	7.2	1	12
Missouri	10	6.8 ± 3.2	*f*	*f*	1	11	2	11 ± 0.57
Montana	*f*	*f*	*f*	*f*	3	13 ± 5.6	2	12 ± 8.1
Nebraska	*f*	*f*	*f*	*f*	1	11	*f*	*f*
Nevada	6	14 ± 5.7	*f*	*f*	4	11 ± 5.6	3	8.2 ± 4.9
New Hampshire	*f*	*f*	11	10 ± 1.0	*f*	*f*	*f*	*f*
New Jersey	23	6.1 ± 4.8	66	7.7 ± 2.3	1	11.4	*f*	*f*

Table 39. (continued)

State	ORNL[b]		Levin[c]		Lindekin[d]		Beck[e]	
	No. of locations	Mean exposure rate (μR/h)	No. of locations	Mean exposure rate (μR/h)	No. of locations	Mean exposure rate (μR/h)	No. of locations	Mean exposure rate (μR/h)
New Mexico	13	10 ± 5.4	*f*	*f*	2	13 ± 0.85	*f*	*f*
New York	*f*	*f*	48	8.9 ± 1.6	3	10 ± 3.2	*f*	*f*
North Carolina	8	8.2 ± 6.5	67	8.0 ± 1.9	2	7.0 ± 4.4	15	15 ± 6.1
North Dakota	*f*	*f*	*f*	*f*	2	9.9 ± 1.7	*f*	*f*
Ohio	11	6.9 ± 5.0	4	10 ± 0.85	1	11	*f*	*f*
Oklahoma	*f*	*f*	*f*	*f*	1	9.7	*f*	*f*
Oregon	9	11 ± 6.6	*f*	*f*	4	8.6 ± 1.4	2	7.6 ± 2.8
Pennsylvania	32	6.7 ± 5.0	10	10 ± 1.5	2	11 ± 4.5	*f*	*f*
Rhode Island	*f*	*f*	4	10 ± 1.4	1	10	*f*	*f*
South Carolina	*f*	*f*	50	8.1 ± 1.6	2	12 ± 5.4	16	10 ± 5.2
South Dakota	*f*	*f*	*f*	*f*	2	10 ± 1.1	8	11 ± 3.5
Tennessee	12	6.4 ± 4.8	20	9.5 ± 1.2	1	9.4	2	11 ± 0.14
Texas	10	3.3 ± 3.0	*f*	*f*	10	8.9 ± 5.9	2	6.4 ± 8.5
Utah	32	8.7 ± 4.5	*f*	*f*	2	14 ± 9.6	56[g]	9.8 ± 3.5[g]
Vermont	*f*	*f*	3	9.1 ± 0.92	2	13 ± 3.5	*f*	*f*
Virginia	13	7.4 ± 5.8	43	8.5 ± 1.5	2	9.9 ± 3.4	*f*	*f*
Washington	*f*	*f*	*f*	*f*	3	8.0 ± 7.1	14	5.5 ± 2.2
West Virginia	11	7.7 ± 3.9	*f*	*f*	1	8.7	*f*	*f*
Wisconsin	*f*	*f*	*f*	*f*	1	8.8	1	9.6
Wyoming	13	14 ± 5.2	*f*	*f*	2	16 ± 5.2	6	9.8 ± 3.7
U. S. Average	327	8.5 ± 4.1	1102	9.2 ± 2.4	107	10 ± 4.9	114	9.9 ± 4.3

[a] State averages are given as the arithmetic mean and standard deviation (2σ).

[b] Tabulated from Table 34.

[c] From ref. 11.

[d] From ref. 14.

[e] From ref. 7. Includes contribution from fallout.

[f] No data reported.

[g] Additional data provided in ref. 15.

Table 40. Background radionuclide concentrations in surface soil – World averages[a]

Radionuclide	Radionuclide concentration in soil (pCi/g)	
	Typical range	World average
^{226}Ra	0.49-1.98	0.79
^{238}U	0.33-1.32	0.66
^{232}Th	0.22-1.31	0.65

[a]Adapted from ref. 18.

Table 41. Correlation statistics for background measurements

Regression analysis	Variables in model		No. of observations	r^2
	Dependent	Independent		
Linear	Gamma	^{238}U	327	0.11
	Gamma	^{226}Ra	319	0.12
	Gamma	^{232}Th	302	0.23
	Gamma	^{226}Ra, ^{238}U	297	0.12
	Gamma	^{232}Th, ^{238}U	297	0.24
	Gamma	^{226}Ra, ^{232}Th	297	0.25
	Gamma	^{226}Ra, ^{232}Th, ^{238}U	297	0.25
Logarithmic	Gamma	^{238}U	327	0.15
	Gamma	^{226}Ra	319	0.15
	Gamma	^{232}Th	302	0.18
	Gamma	^{226}Ra, ^{238}U	297	0.15
	Gamma	^{232}Th, ^{238}U	297	0.20
	Gamma	^{226}Ra, ^{232}Th	297	0.20
	Gamma	^{226}Ra, ^{232}Th, ^{238}U	297	0.20

EXTERNAL GAMMA SURVEY METER

External gamma exposure rates are measured with an organic-filled Geiger-Mueller (G-M) tube that is 15-cm long with a 30 mg/cm^2 glass wall. This dosimeter is a RCL 10-60 micro G-M counter filled with neon, argon, and a halogen quenching agent. The probe is surrounded by an energy compensated shield of tin and lead. Pulses from this unit are counted with a battery-powered portable scaler (Fig. I-A). Geiger-Mueller counters are not typically used for measuring gamma fields due to a peak response at low photon energies. However, perforated layers of tin (1.0 mm on sides and end) and lead (0.3 mm on sides, 0.1 mm on end) are used as energy compensation filters to flatten the peak response at photon energies below approximately 200 keV. As shown in Fig. I-B, the response of the Phil tube with the perforated shield is independent of gamma energies down to 50 keV, within ±12%. The polar response obtained with the same counter and shield is shown in Fig. I-C.

National Bureau of Standards (NBS) traceable sealed sources of ^{137}Cs and ^{226}Ra are used for calibration. Detector response is typically 1 mR/hr = 3400 cpm. Each external background exposure measurement represents the mean of at least three one-minute counts. Instrument background is subtracted out in the final determination of exposure rate.

Errors associated with the use of the "Phil" tube in measuring low-levels of gamma radiation can be quite large. Individual measurement errors in gamma-ray fields of less than 10 μR/h were found to range from 50% to over 100% at the 95% confidence level. For exposure rates greater than 10 μR/h, the measurement error ranged from 25% to 50%. Due to this variability at low exposure rates, use of this instrument for background determination has been discontinued. Exposure rate measurements in the current ORNL survey program are made with a Reuter-Stokes RSS-111 Pressurized Ion Chamber.

ORNL-Photo 6713-76

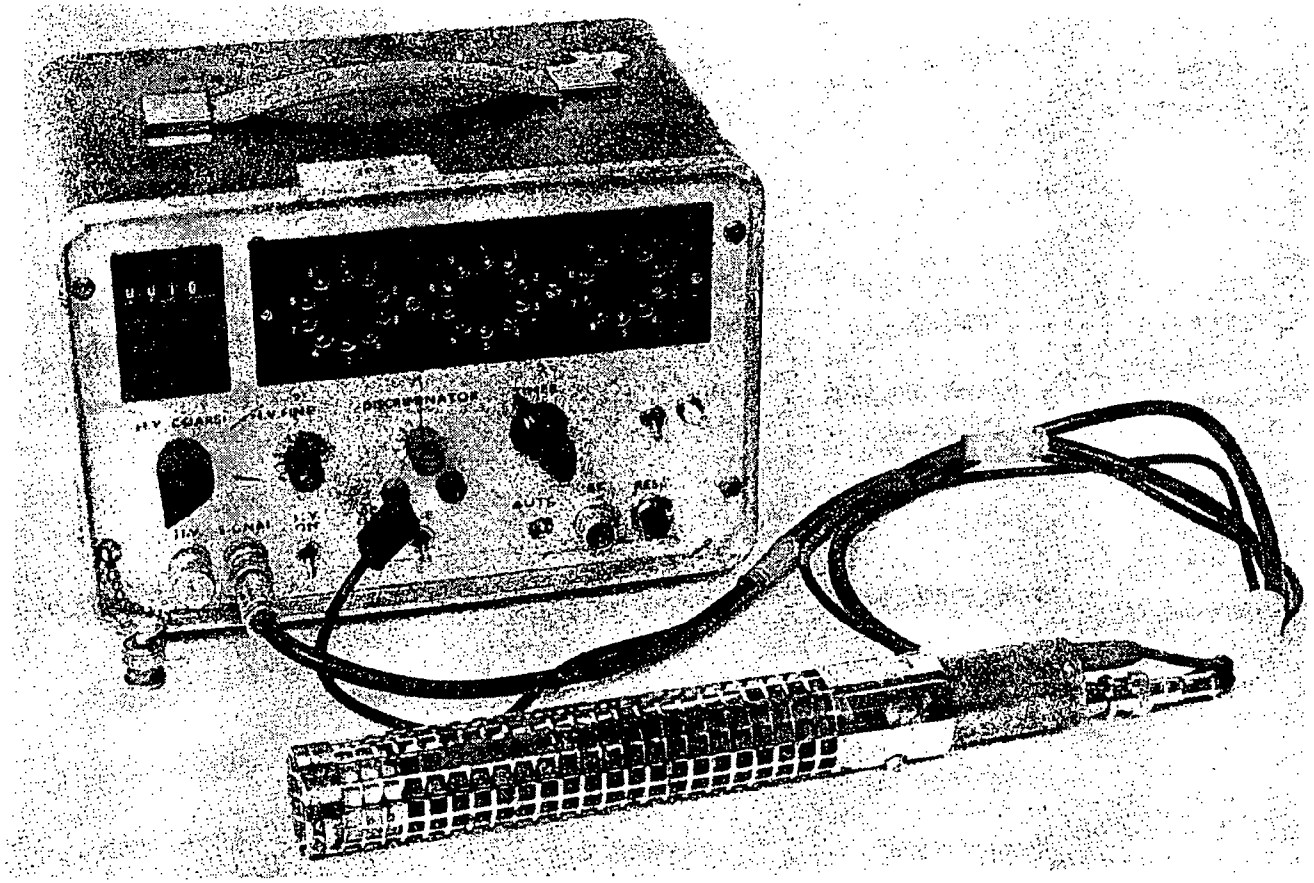

Fig. I-A. Glass-walled, organic-filled Geiger-Mueller (G-M) tube with a battery-powered portable scaler.

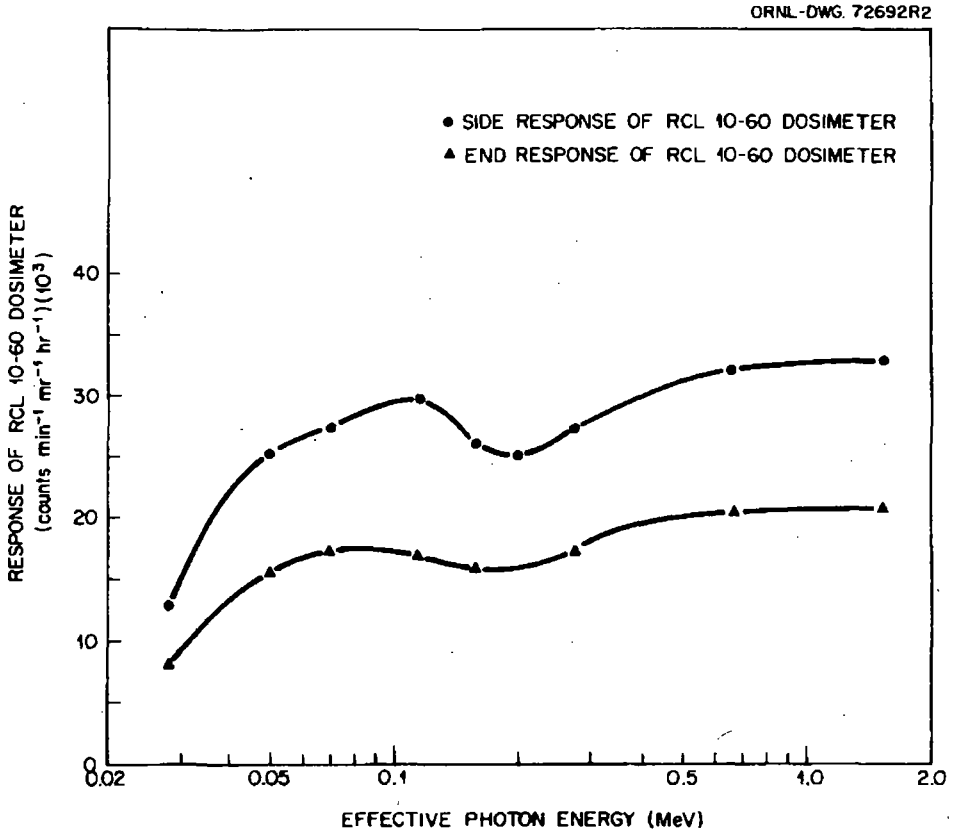

Fig. I-B. Response of Philips 18509 shielded counter as a function of gamma-ray energy.

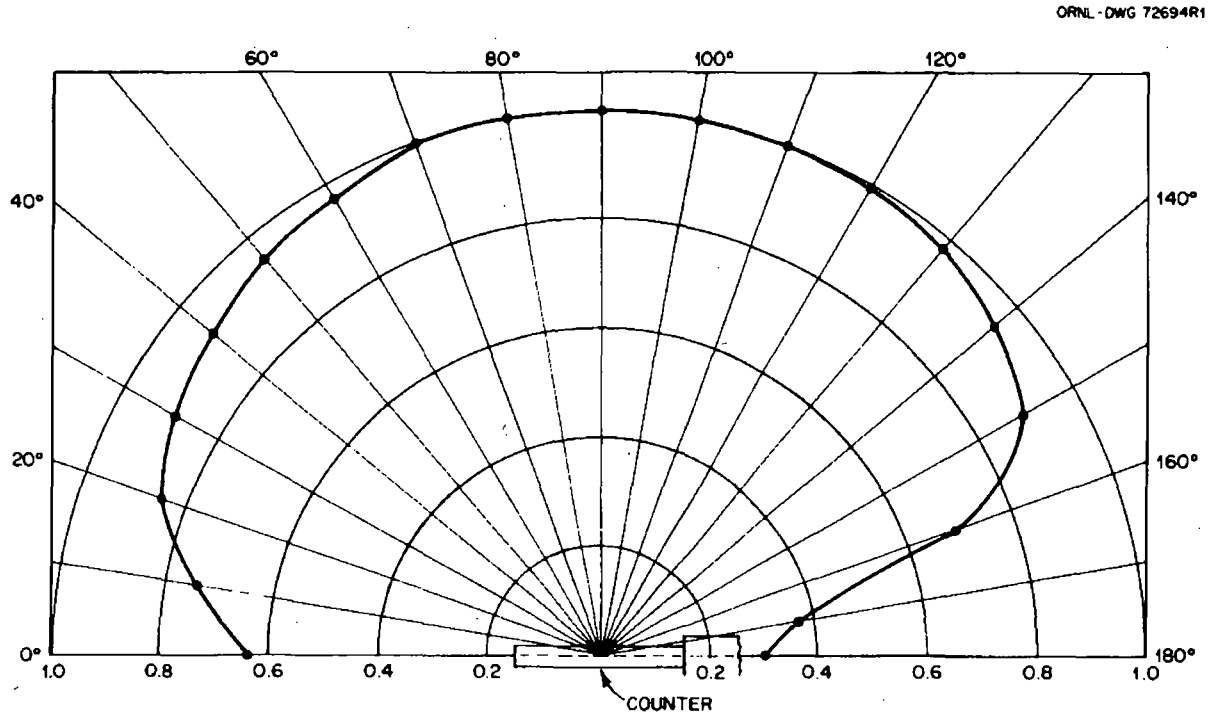

Fig. I-C. Relative angular response of Philips 18509 counter, with perforated shield for ^{60}Co gamma rays.

ANALYSIS FOR ^{226}Ra AND ^{232}Th USING THE Ge(Li) DETECTION SYSTEM

Soil samples for ^{226}Ra and ^{232}Th analysis are dried for 24 h at 110°C and then pulverized to a particle size no greater than 500 μm in diameter (-35 mesh). Aliquots from this dried sample are transferred to 30-cm^3 polyethylene bottles (standard containers for liquid scintillation samples), weighed and stored for approximately 30 days to allow for buildup of radon and radon daughters. These bottled samples are then analyzed on the geranium lithium-drifted [Ge(Li)] detector system of the Off-Site Pollutant Measurements Group at ORNL.

A holder for twelve of the polyethylene bottles and a background shield have been designed for use with a 50-cm^3 Ge(Li) detector system (see Figs. II-A, II-B). During counting of the samples, the holder is used to position ten of the sample bottles around the cylindrical surface of the detector, parallel to and symmetric about its axis, and two additional bottles across the end surface of the detector, perpendicular to and symmetric with its axis. With a 300-cm^3 sample and a graded shield developed for use with the system, it is possible to measure less than 1 pCi/g of ^{232}Th or ^{226}Ra with an error of ±10% or less. The minimum detectable concentration (MDC) for the system, considering the background of the counting system, is generally about 0.3 pCi/g.

Pulses produced by the Ge(Li) crystal are sorted by a 4096-channel analyzer (see Fig. II-C), stored on magnetic tape, and subsequently entered into a computer program, which uses a least squares method to identify radionuclides corresponding to those gamma-ray lines found in the sample. The program, which is accessible through a remote terminal, relies on a library of radioisotopes, which contains approximately 700 isotopes and 2500 gamma-rays, and which runs continuously on the IBM-360 system at ORNL. In identifying and quantifying ^{226}Ra, six principal gamma-ray lines are analyzed. Most of these are from ^{214}Bi and correspond to 295, 352, 609, 1120, 1765, and 2204 keV. For analysis of ^{232}Th, seven gamma lines of its daughters are analyzed (239, 338, 583, 795, 911, 969, and 2615 keV).

NEUTRON ABSORPTION TECHNIQUE FOR ^{238}U ANALYSIS*

Following the initial soil sample drying and pulverizing, a 30 cm^3 aliquot is sent to the Analytical Chemistry Division of ORNL for ^{238}U analysis by neutron activation. The concentration of ^{235}U in the soil sample is determined by counting delayed neutrons emitted from fission products produced by neutron activation of the ^{235}U in the sample. Neutron activation of the samples are made in the pneumatic tube irradiation facility of the Oak Ridge Research Reactor. Following exposure to a thermal neutron flux of approximately 6×10^{13} n/cm^2-s, a count of the delayed-neutron activity is made using a paraffin moderator with a BF_3 tube detector assembly having a neutron counting efficiency of about 5%. The ^{235}U content of a test sample is obtained by comparing its delayed-neutron count to that obtained with a comparator sample containing a known quantity of ^{235}U. Calculations are then made utilizing the following equation:

$$^{235}U \text{ in test sample} = {}^{235}U \text{ in comparator sample} \left(\frac{\text{Net count of test sample}}{\text{Net count of comparator sample}}\right)$$

The ^{238}U concentration is then calculated assuming that 0.72% of natural uranium is ^{235}U. The precision of this method is approximately ±3% (expressed as the relative standard deviation for 2σ or 95% confidence intervals), with a lower limit of detection of ~40 ppb (10^{-2} pCi/g) for ^{238}U.

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*F. F. Dyer, J. F. Emery, and G. W. Leddicotte, *A Comparative Study of the Neutron Activation Analysis of Uranium by Delayed Neutron Counting*, ORNL-3342 (October 1962).

ORNL-Photo 2172-75

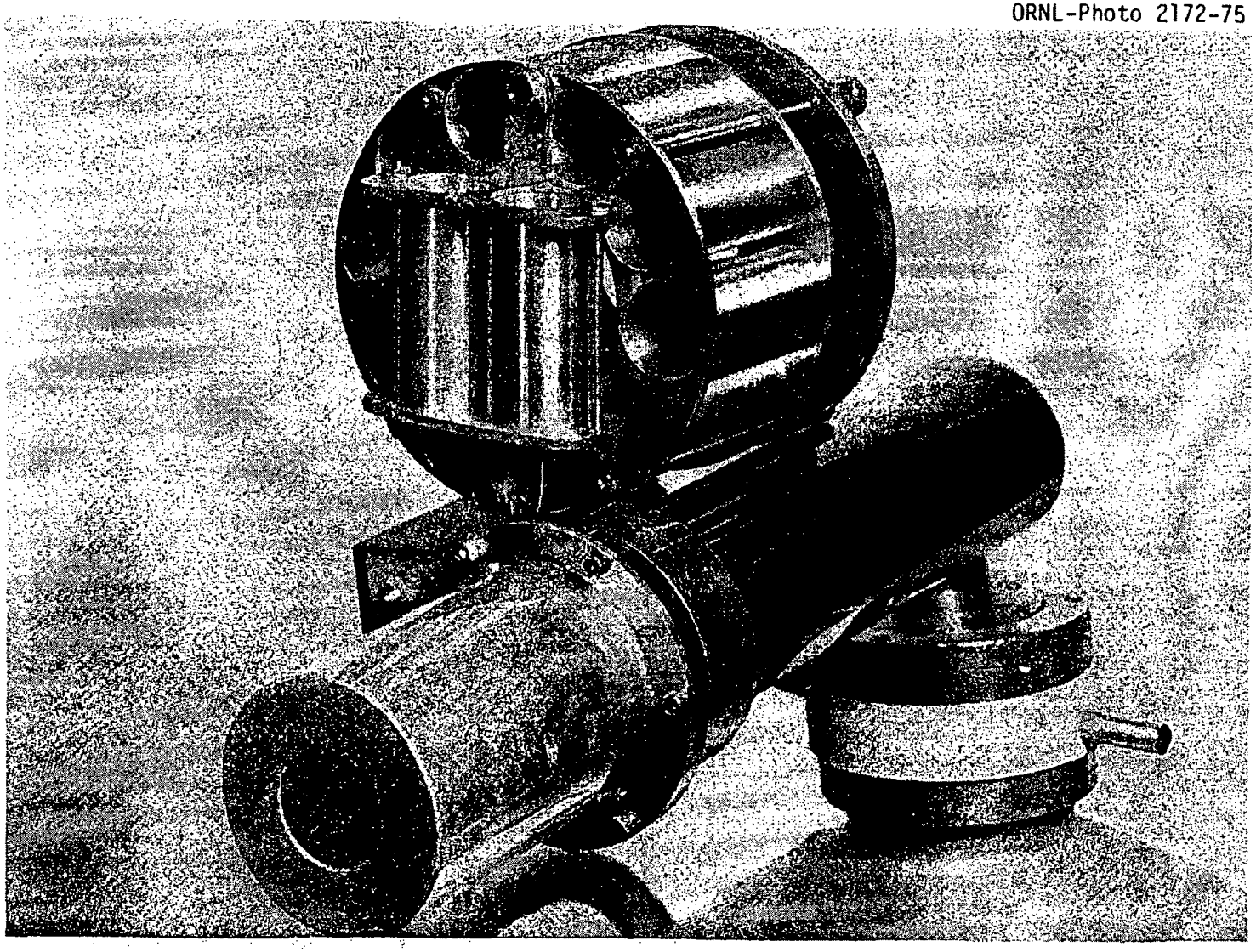

Fig. II-A. Soil sample holder above the Ge(Li) detector.

ORNL-Photo 2171-75

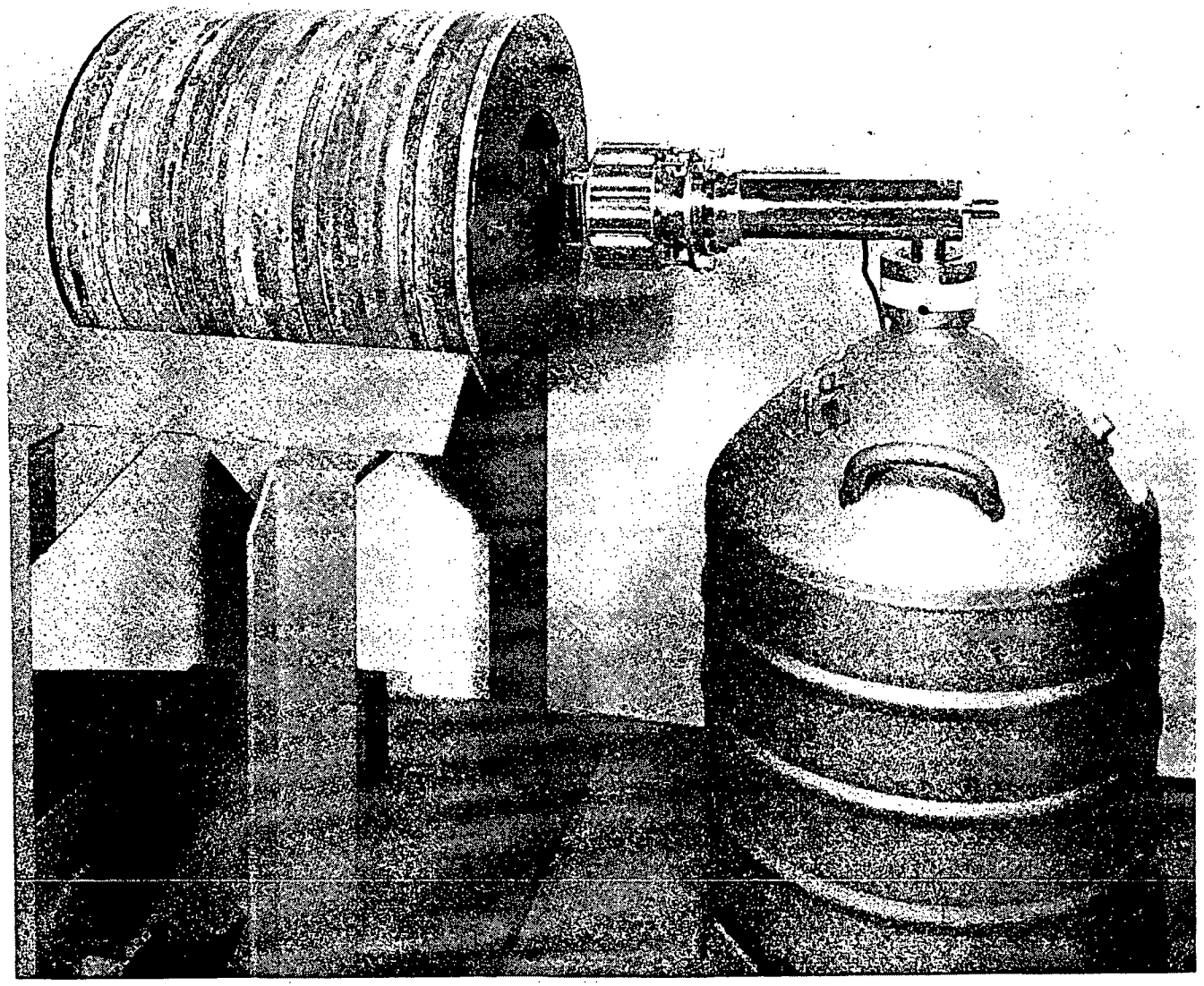

Fig. II-B. Soil sample holder attached to Ge(Li) detector.

ORNL-Photo 6711-76

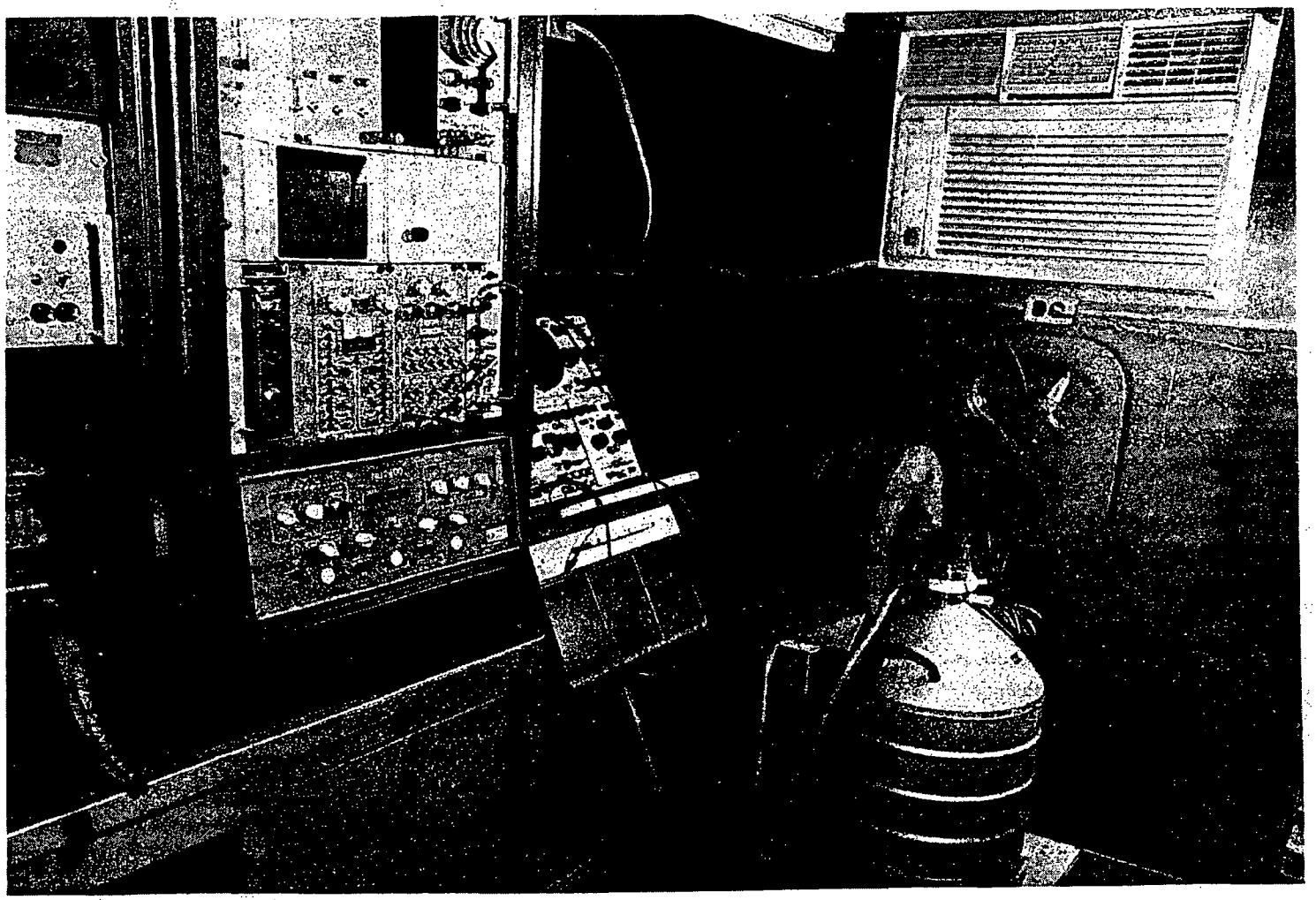

Fig. II-C. Ge(Li) detector and holder inside lead shield with associated 4096-channel analyzer.

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